Biological Impairment in the Mud Creek Watershed

French Broad River Basin
Henderson County

June 2003

North Carolina Department of Environment and Natural Resources
Division of Water Quality
Planning Branch

Prepared for the Clean Water Management Trust Fund

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APPENDICES

ACKNOWLEDGEMENTS

A number of people and agencies were helpful in data collection and analysis. Tennessee Valley Authority worked closely with NC Division of Water Quality (DWQ) to meet project needs for land use/cover and riparian area GIS data, providing the Integrated Pollutant Source Identification (IPSI) dataset. Kristin Cozza of the NC Wetlands Restoration Program was instrumental in securing funds for the IPSI. Marilyn Westphal of UNCA's Environmental Quality Institute provided water chemistry data collected by the Volunteer Water Information Network.

A number of local extension agents have provided information on agricultural practices, including Jim Walgenbach, Marvin Owings, and Mark Lancaster. Bob Carter of the Natural Resources Conservation Service has been a continual source of information on land use history, natural resources and agriculture.

The Mud Creek Watershed Restoration Council has been integral to development of meaningful management strategies.

Executive Summary

Introduction

This report presents the results of the Mud Creek watershed water quality assessment, conducted by the North Carolina Division of Water Quality (DWQ) with financing from the Clean Water Management Trust Fund (CWMTF). Mud Creek, Clear Creek, and Bat Fork are considered impaired by the DWQ because they are unable to support acceptable communities of aquatic organisms. The goal of the assessment was to provide the foundation for future water quality restoration activities in the Mud Creek watershed by: 1) identifying the most likely causes of biological impairment; 2) identifying the major watershed activities and pollution sources contributing to those causes; and 3) outlining a general watershed strategy that recommends restoration activities and best management practices (BMPs) to address the identified problems.

Study Area and Stream Description

Mud Creek, Bat Fork, and Clear Creek are tributaries of the French Broad River, located in Henderson County south of Asheville (see Figure 1.1). The watershed drains approximately 113 mi^2 (293 km^2) within DWQ subbasin 040302. For this study, the watershed was divided into smaller hydrological units for analysis, namely Clear Creek, Devils Fork, Bat Fork, upper Mud Creek, and lower Mud Creek (see Figure 2.2). Although 45 percent of the watershed is forested, the wide floodplains and rolling hills typical of this watershed are often cleared for agricultural (row crops, apple orchards, pasture), residential, and commercial use. Upper Mud Creek, Clear Creek, and Devils Fork subwatersheds are largely rural; much of the towns of Hendersonville, Flat Rock, and part of Laurel Park and associated suburban development occur in the lower Mud Creek and Bat Fork subwatersheds. Extensive areas of apple orchards are in the Clear Creek and Devils Fork subwatersheds, and 10 percent or more of each subwatershed is in pasture. Row crops are grown along many floodplain areas. Many lower gradient streams (including Mud Creek and Bat Fork) have been channelized and are incised.

Results from historical monitoring demonstrate severely impacted benthic macroinvertebrate communities in Mud Creek, Bat Fork, and Clear Creek and some of its tributaries. North Carolina's 2002 303(d) list designates the entire lengths of Mud Creek, Clear Creek, and Bat Fork as impaired and notes that Mud Creek was historically listed for sediment, and Bat Fork and Clear Creek suffer from habitat degradation.

Approach

A wide range of data was collected to evaluate potential causes and sources of impairment. Data collection activities included: benthic macroinvertebrate sampling; assessment of stream habitat, morphology, and riparian zone condition; water and bed sediment quality sampling to evaluate stream chemistry and toxicity; and characterization of watershed land use, conditions and pollution sources. Data collected during the study are presented in Sections 4 through 7 of the report.

Conclusions

The Mud Creek watershed is impacted by both rural and urban stressors, including toxicants, stormflow scour, excess nutrients, lack of upstream colonization sources, and habitat degradation. The most likely causes of impairment and contributing stressors were identified based the available data and are listed for each subwatershed below (see Sections 4 through 7 for additional discussion).

Problems, or stressors, isolated in this study are categorized as either a cause of impairment, a contributing stressor, or a potential cause or contributor. A cause of impairment is either primary (the most critical stressor, capable of causing impairment by itself) or cumulative (one of several stressors that cumulatively cause impairment). A contributing stressor contributes to biological degradation but does not cause impairment. A potential cause or contributor is a stressor that has been documented, but its contribution to impairment is unknown.

Bat Fork

Bat Fork suffers from severe habitat degradation due to channelization, removal of riparian vegetation, and cattle access to it and its tributaries. A primary cause of impairment was not identified, and instead there are a number of cumulative causes of impairment, including exposure to toxicants, lack of upstream colonization sources, and habitat degradation—sedimentation, lack of riffles, pools, and bends, and lack of organic microhabitat.

Upper Mud Creek

Mud Creek does not appear to be impaired above Walnut Cove Rd, but the biological community is severely impacted below Walnut Cove Rd. Upper Mud Creek suffers from chronic effects of channelization, removal of riparian vegetation, and cattle access to it and its tributaries. Although the aquatic habitat degradation that results from these system-wide problems is severe, the key stressor for benthic macroinvertebrate community below Walnut Cove Rd. is toxicity. The source of this toxicity is most likely tomato pesticides in the upper part of the impaired area, and multiple sources of toxicity exist in the lower portion, including agricultural, golf course, and residential pesticides.

1. The primary cause of impairment is exposure to toxicants. The most likely toxicants for the Berea Church Rd. area are tomato pesticides.
2. Habitat degradation—sedimentation, lack of riffles, pools, and bends, and lack of organic microhabitat (leaves, sticks, large wood)—are cumulative causes of impairment.

Clear Creek and Upper Devils Fork (source to Interstate 26 area)

Although some level of habitat degradation is present in these streams, there is still enough in-stream habitat to support healthy benthic macroinvertebrate communities. Habitat degradation is severe in some highly modified tributaries, which contribute large amounts of sediment to the watershed.

1. Based upon analysis of benthic macroinvertebrate data, exposure to toxicants is considered to be the primary cause of impairment. Pesticides from apple orchards and/or row crops are the most likely source of toxicity, although the specific pesticides responsible (including the roles of past use pesticides vs. pesticides in current use) and the relative contribution of row crops and apple orchards cannot be determined with the available data.
2. Contributing stressors are nutrient enrichment and sedimentation.
3. Metals are present at higher levels in stormflows and are a potential cause or contributor to impairment in Clear Creek.

Lower Devils Fork (I-26 area to Johnson Drainage Ditch)
Lower Devils Fork is extensively channelized and diked and lacks healthy riparian vegetation. It also suffers from exposure to toxicants, which come from agricultural activities upstream and stormwater runoff from extensive commercial areas.

1. A primary cause of impairment was not identified, and instead there are a number of cumulative causes of impairment, including exposure to toxicants (most likely pesticides and urban toxicants), stormflow scour, and habitat degradation—sedimentation, lack of riffles, pools, and bends, and lack of organic microhabitat.
2. Nutrient enrichment is considered a contributing stressor.

Lower Mud Creek (Erkwood Rd. to mouth)
Since this is downstream of Clear Creek, Devils Fork, Bat Fork, and upper Mud Creek, it reflects many of the problems seen in these upper subwatersheds. A number of stressors act in concert to impact the biological community and are considered cumulative causes of impairment, including exposure to toxicants (most likely pesticides and urban toxicants), stormflow scour, lack of upstream colonization sources, and habitat degradation—sedimentation and lack of riffles, pools, and bends.

Management Strategies

The objectives of efforts to improve stream integrity are to create water quality and habitat conditions to support a diverse and functional biological community in this watershed. This report is not intended to specify particular administrative or institutional mechanisms for implementing remedial practices, but only to describe the types of actions that should be taken to place Mud Creek, Clear Creek, and Bat Fork on the "road to improvement". The following actions are necessary to address current sources of impairment in the Mud Creek watershed and prevent future degradation. Actions four and five are proposed based on current understanding of apple and row crop pesticide delivery and impacts; strategies should be further refined based on cooperative research by DWQ, NC Department of Agriculture and Consumer Services, NC Division of Soil and Water Conservation, NC State University, NC Cooperative Extension Service, Natural Resources Conservation Service, and other agencies. Actions one through five are essential to restoring and sustaining aquatic communities in the watershed.

List of Actions

1. **Feasible and cost-effective stormwater retrofit projects should be implemented throughout the developed portions of the watershed to mitigate the hydrologic effects of development** (increased stormwater volumes and increased frequency and duration of erosive and scouring flows). This should be viewed as a long-term process. Although there are many uncertainties, costs of at least $1 million per square mile can probably be anticipated.
   a) Over the short-term, currently feasible retrofit projects should be identified and implemented.
   b) In the longer term, additional retrofit opportunities should be sought out in conjunction with infrastructure improvements and redevelopment of existing developed areas.
2. **A strategy to address toxic inputs from developed areas should be developed and implemented, including a variety of source reduction and stormwater treatment methods.** As an initial framework for planning toxicity reduction efforts, the following general approach is proposed:

a) Implementation of available best management practice (BMP) opportunities for control of stormwater volume and velocities. Recommended above to lessen impacts of scour, these BMPs will also remove toxicants from the stormwater system.
b) Development of a stormwater and dry weather sampling strategy in order to facilitate the targeting of pollutant removal and source reduction practices.
c) Implementation of stormwater treatment BMPs, aimed primarily at pollutant removal, at appropriate locations.
d) Development and implementation of a broad set of source reduction activities focused on: reducing nonstorm inputs of toxicants; reducing pollutants available for washoff during storms; and managing water to reduce storm runoff. Suggestions for potential source reduction practices are provided.

3. **Stream channel restoration activities should be implemented in order to improve aquatic habitat.**
   a) In order to solve chronic channel instability and habitat problems, restoration of profile, pattern, and dimension should be performed on the channels of upper Mud Creek and Bat Fork. If this option is not pursued, at least woody riparian vegetation should be planted and the streams allowed to heal themselves over time.
   b) In urban areas of Mud Creek, lower Devils Fork, and Johnson Drainage Ditch, undeveloped adjacent lands should be acquired and their floodplain function enhanced, restoring hydrological connection of the floodplains with streams and creating riparian wetlands. In conjunction with the floodplain work, stream restoration should be performed where infrastructure allows.
   c) Woody riparian vegetation should be planted along lower Mud Creek.
   d) Tributaries contributing large amounts of sediment due to in-stream instability should be stabilized.
   e) Livestock should be excluded from mainstem and tributary streams.
4. **Effective BMPs to prevent row crop pesticides from entering streams should be used to address four potential delivery mechanisms**:
   a) Pesticide mixing areas near streams should be replaced with agrichemical mixing facilities that are away from streams and properly manage pesticides.
   b) Riparian vegetation should be planted and stormwater flow diffused through this buffer to reduce pesticides in stormwater runoff.
   c) Backflow prevention systems should be installed in fertigation/chemigation systems.
   d) Pesticide injection into chemigation systems that contain media filters should be on the outlet side of all media filters.
   e) Filter backwash should be recycled or directed away from surface waters.
   f) Eroding stream banks should be stabilized to minimize erosion of pesticide-contaminated sediments into streams.
5. Apple growers have taken many steps to reduce the likelihood of pesticide contamination of streams. Pesticides used now are much less persistent and used more conservatively than in the past. There is a much higher awareness of proper pesticide handling and mixing procedures. In addition, many farmers are active in an Integrated Pest Management (IPM) program. **In order to further mitigate pesticide impacts, effective BMPs to prevent pesticide contamination of streams from apple orchards should be developed and used**, including:
   a) Pesticide mixing areas near streams should be replaced with agrichemical mixing facilities that properly manage pesticides and are away from streams.

b) Riparian vegetation should be planted and stormwater flow diffused through this buffer to reduce pesticides in stormwater runoff.
c) Funding for IPM should be made available to all farmers in the watershed.
d) Abandoned apple orchards should be dismantled with proper sediment and erosion control to insure that sediments that may contain pesticides stay on site.
e) Practices to minimize spray drift should be developed and promoted.
f) Eroding stream banks should be stabilized to minimize erosion of pesticide-contaminated sediments into streams.
g) Better funding sources should be developed to enable farmers to transition to organic apple growing.

6. Further monitoring should be performed to determine delivery mechanisms of current and past use pesticides and the role of past use pesticides in current biological community degradation. In addition, further monitoring of stormflows should be performed in the Clear Creek subwatershed to determine the role of metals in biological impairment.
7. In order to prevent further stream channel and biological community degradation, effective post construction stormwater management must be used in the study area, especially in the rapidly developing US 25, US 176, US 64, and I-26 corridors, including:
    a) Rapid implementation of the Phase II post-construction stormwater measures in Hendersonville, Flat Rock, and Laurel Park in order to minimize future development occurring under current requirements.
    b) A county-wide threshold for the use of stormwater controls that is no higher than 10% built upon area. To prevent existing unstable conditions in Mud Creek and its tributaries from deteriorating further, post-construction stormwater control requirements should be applied to all but the lowest density development.
    c) Active promotion of infiltration practices and other approaches to limit stormwater volume in both low density and high density development.
    d) Identification of wetland restoration projects or other watershed-based efforts to mitigate for post-construction stormwater impacts that will not otherwise be controlled.
8. Henderson County should develop a sediment and erosion control program or NC Division of Land Resources should refine its present program, with specific provisions to address smaller sites and road and site development on steep slopes. Staffing levels sufficient to support effective enforcement are essential.
9. A watershed education program should be developed with the goal of reducing current stream damage and preventing future degradation. At a minimum, the program should include elements to address the following issues:
    a) Redirecting downspouts to pervious areas rather than routing these flows to driveways or gutters.
    b) Protecting existing wooded riparian areas on perennial, intermittent, and ephemeral streams.
    c) Replanting native riparian vegetation on perennial, intermittent and ephemeral channels where such vegetation is absent.
    d) Reducing and properly managing pesticide and fertilizer use.

Section 1
Introduction

This report presents the results of the Mud Creek watershed water quality assessment, conducted by the North Carolina Division of Water Quality (DWQ) with financing from the Clean Water Management Trust Fund (CWMTF). Mud Creek and its tributaries, Clear Creek and Bat Fork, are considered impaired by the DWQ because they are unable to support acceptable communities of aquatic organisms. Prior to this study, the reasons for these conditions were unknown, inhibiting the development of water quality improvement efforts in this watershed.

Part of a larger effort to evaluate impaired streams across North Carolina, this study was intended to evaluate the potential causes of biological impairment and to suggest appropriate actions to improve stream conditions. The CWMTF, which allocates grants to support voluntary efforts to address water quality problems, is seeking DWQ's recommendations regarding the types of activities it could fund in these watersheds to improve water quality. Both the DWQ and the CWMTF are committed to encouraging locally based initiatives to protect streams and to restore waters that are degraded.

1.1 Study Area Description

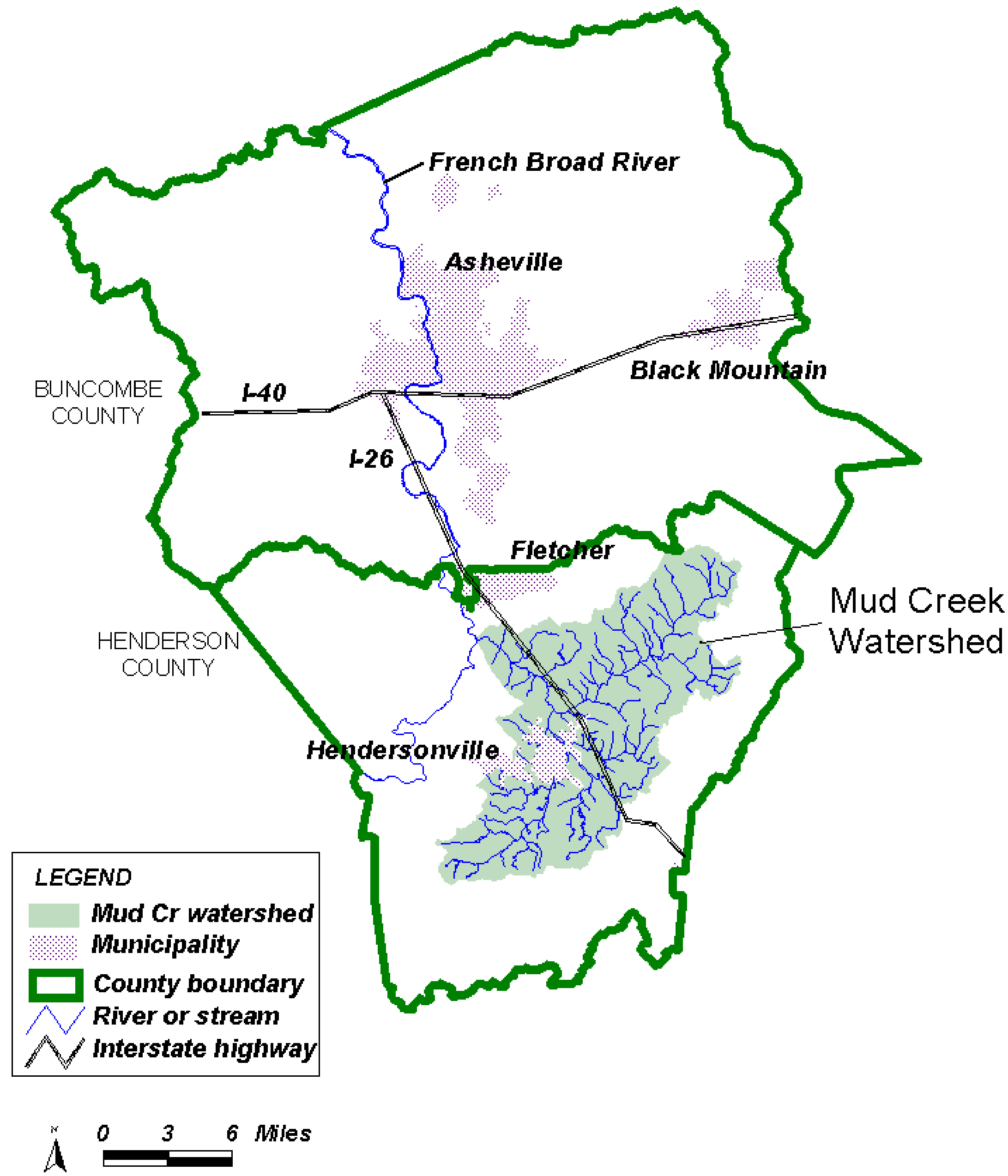
Mud Creek, Bat Fork, and Clear Creek are tributaries of the French Broad River, located in Henderson County south of Asheville (Figure 1.1). The watershed drains approximately 113 mi^2 (293 km^2) within DWQ subbasin 040302. North Carolina's 2002 303(d) list designates Mud Creek as impaired for its entire length (18.4 mi or 29.6 km, DWQ index numbers 6-55a and 6-55b) (NC DWQ, 2002). Clear Creek is impaired for its entire length, as well (18 mi or 29 km, DWQ index numbers 6-55-11-(1) and 6-55-11-(5)). The entire 4.8 mi (or 7.7 km) length of Bat Fork is considered impaired (DWQ index number 6-55-8-1).

1.2 Study Purpose

The Mud Creek watershed assessment is part of the Watershed Assessment and Restoration Project (WARP), a study of eleven watersheds across the state being conducted from 2000 to 2002 with funding from the CWMTF (Table 1.1). The goal of the project is to provide the foundation for future water quality restoration activities in the eleven watersheds by:

1. Identifying the most likely causes of biological impairment (such as degraded habitat or specific pollutants);
2. Identifying the major watershed activities and sources of pollution contributing to those causes (such as stormwater runoff from particular urban or rural areas or stream bank erosion); and
3. Outlining a watershed strategy that recommends restoration activities and best management practices (BMPs) to address the identified problems and improve the biological condition of the impaired streams.

Figure 1.1. Location of the Mud Creek Watershed



This investigation focused primarily on aquatic life use support issues. It was intended to assess the major issues related to biological impairment as comprehensively as possible within the time frame of the study. While not designed to address other important issues in the Mud Creek watershed, such as bacterial contamination or flooding, the report discusses those concerns where existing information allows.

Table 1.1 Study Areas Included in the Watershed Assessment and Restoration Project

Watershed	River Basin	County
Toms Creek	Neuse	Wake
Upper Swift Creek	Neuse	Wake
Little Creek	Cape Fear	Orange, Durham
Horsepen Creek	Cape Fear	Guilford
Little Troublesome Creek	Cape Fear	Rockingham
Upper Clark Creek	Catawba	Catawba
Upper Cullasaja River/ Mill Creek	Little Tennessee	Macon
Morgan Mill/Peter Weaver Creeks	French Broad	Transylvania
Mud Creek	French Broad	Henderson
Upper Conetoe Creek	Tar-Pamlico	Edgecombe, Pitt, Martin
Stoney Creek	Neuse	Wayne

1.3 Study Approach and Scope

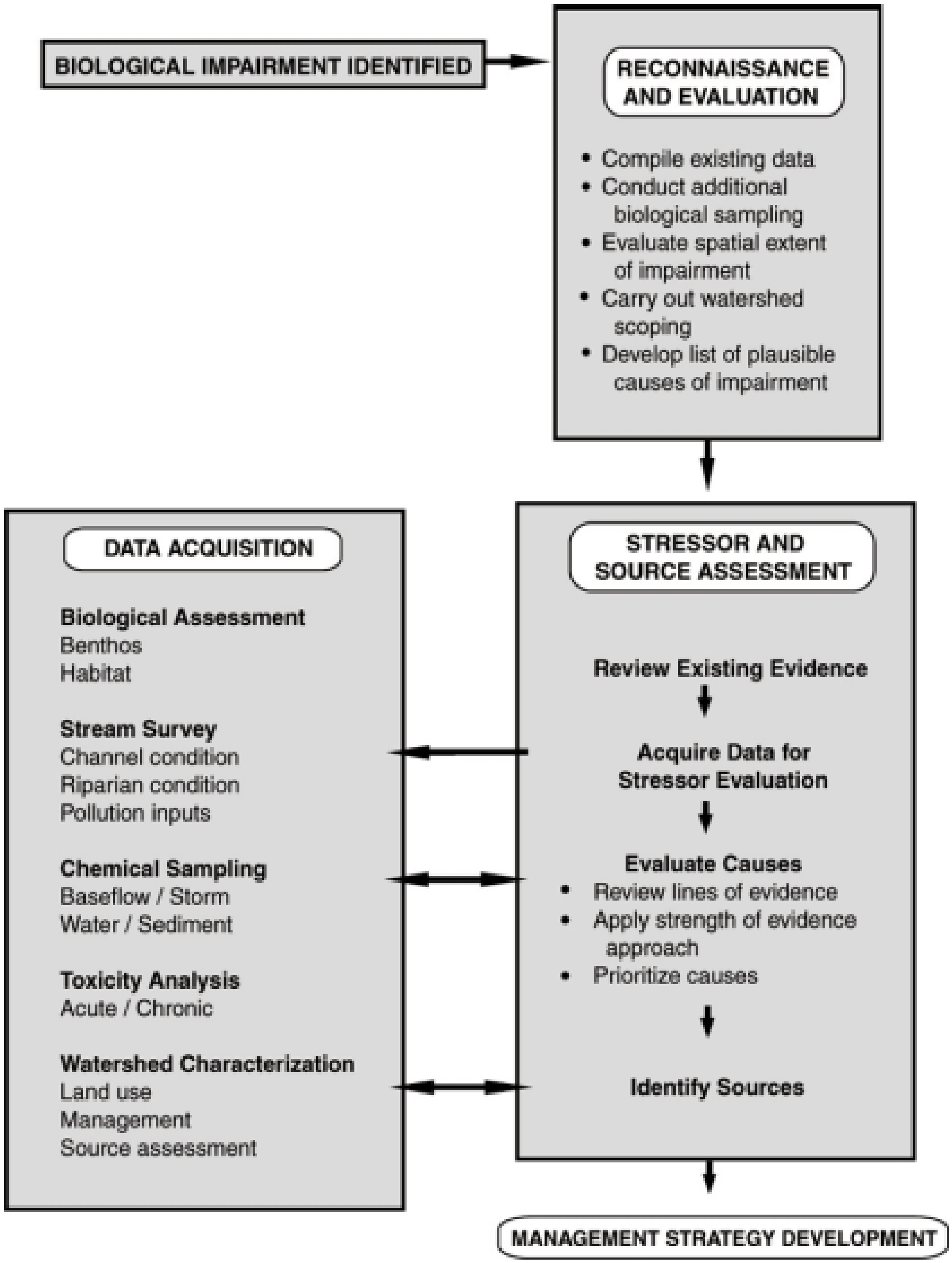
The first objective, identification of the likely causes of impairment is a critical building block, because addressing subsequent objectives depends on this step (Figure 1.2). Determining the primary factors causing biological impairment is a significant undertaking that must address a variety of issues (see the Background Note "Identifying Causes of Impairment"). While identifying causes of impairment can be attempted using rapid screening level assessments, a more detailed approach has been taken in order to maximize the opportunity to reliably and defensibly identify causes and sources of impairment within the time and resource framework of the project. This provides a firmer scientific foundation for the collection and evaluation of evidence, facilitates the prioritization of problems for management, and offers a more robust basis for the commitment of resources. EPA's recently published guidance for stressor identification envisions that causes of impairment be evaluated in as rigorous a fashion as is practicable (USEPA, 2000b).

1.3.1 Study Approach

The general conceptual approach used to determine causes of impairment in the Mud Creek watershed was (Foran and Ferenc, 1999; USEPA, 2000b):

- *Identify the most plausible potential (candidate) causes* of impairment in the watershed, based upon existing data and initial watershed reconnaissance activities.

Figure 1.2 Overview of Study Activities



Background Note: Identifying Causes of Impairment

Degradation and impairment are not synonymous. Many streams and other waterbodies exhibit some degree of degradation, that is, a decline from unimpacted conditions. Streams that are no longer pristine may still support good water quality conditions and function well ecologically. When monitoring indicates that degradation has become severe enough to significantly interfere with one of a waterbody's designated uses (such as aquatic life propagation or water supply), the Division of Water Quality formally designates that stream segment as impaired. It is then included on the state's 303(d) list, the list of impaired waters in North Carolina.

Many impaired streams, including those that are the subject of this study, are so rated because they do not support a healthy population of fish or benthic macroinvertebrates (aquatic insects visible to the naked eye). While standard biological sampling can determine whether a stream is supporting aquatic life or is impaired, the cause of impairment can only be determined with additional investigation. In some cases, a potential cause of impairment is noted when a stream is placed on the 303(d) list, using the best information available at that time. These noted potential causes are generally uncertain, especially when nonpoint source pollution issues are involved.

A cause of impairment can be viewed most simply as a stressor or agent that actually impairs aquatic life. These causes may fall into one of two broad classes: 1) chemical or physical pollutants (e.g., toxic chemicals, nutrient inputs, oxygen-consuming wastes); and 2) habitat degradation (e.g., loss of in-stream structure such as riffles and pools due to sedimentation; loss of bank and root mass habitat due to channel erosion or incision). Sources of impairment are the origins of such stressors. Examples include urban and agricultural runoff.

The US Environmental Protection Agency defines causes of impairment more specifically as "those pollutants and other stressors that contribute to the impairment of designated uses in a waterbody" (USEPA, 1997, pp. 1-10). When a stream or other waterbody is unable to support an adequate population of fish or macroinvertebrates, identification of the causes of impairment thus involves a determination of the factors most likely leading to the unacceptable biological conditions.

All conditions that impose stress on aquatic communities may not be causes of impairment. Some stressors may occur at an intensity, frequency and duration that are not severe enough to result in significant degradation of biological or water quality conditions to result in impairment. In some cases, a single factor may have such a substantial impact that it is the only cause of impairment, or clearly predominates over other causes. In other situations several major causes of impairment may be present, each with a clearly significant effect. In many cases, individual factors with predominant impacts on aquatic life may not be identifiable and the impairment may be due to the cumulative impact of multiple stressors, none of which is severe enough to cause impairment on its own.

The difficulty of developing linkages between cause and effect in water quality assessments is widely recognized (Fox, 1991; USEPA, 2000b). Identifying the magnitude of a particular stressor is often complex. Storm-driven pollutant inputs, for instance, are both episodic and highly variable, depending upon precipitation timing and intensity, seasonal factors and specific watershed activities. It is even more challenging to distinguish between those stressors that are present, but not of primary importance, and those that appear to be the underlying causes of impairment. Following are examples of issues that must often be addressed.

- Layered impacts (Yoder and Rankin, 1995) may occur, with the severity of one agent masking other problems that cannot be identified until the first one is addressed.
- Cumulative impacts, which are increasingly likely as the variety and intensity of human activity increase in a watershed, are widely acknowledged to be very difficult to evaluate given the current state of scientific knowledge (Burton and Pitt, 2001; Foran and Ferenc, 1999).
- In addition to imposing specific stresses upon aquatic communities, watershed activities can also inhibit the recovery mechanisms normally used by organisms to 'bounce back' from disturbances.

For further information on use support and stream impairment issues, see the website of DWQ's Basinwide Planning Program at http://h2o.enr.state.nc.us/basinwide/; A *Citizen's Guide to Water Quality Management in North Carolina* (NCDWQ, 2000); EPA's *Stressor Identification Guidance Document* (USEPA, 2000b).

- *Collect a wide range of data* bearing on the nature and impacts of those potential causes.
- *Characterize the causes of impairment* by evaluating all available information using a *strength of evidence approach*. The strength of evidence approach, discussed in more detail in Section 7, involves a logical evaluation of multiple lines (types) of evidence to assess what information supports or does not support the likelihood that each candidate stressor is actually a contributor to impairment.

Project goals extend beyond identifying causes of impairment, however, and include the evaluation of source activities and the development of recommendations to mitigate the problems identified. In order to address all three objectives, activities conducted in the Mud Creek watershed during this study were divided into three broad stages:

1. An initial *reconnaissance stage*, in which existing information was compiled and watershed reconnaissance conducted. At the conclusion of this stage the most plausible candidate causes of impairment were identified for further evaluation.
2. A *stressor-source evaluation stage* that included: collection of information regarding candidate causes of impairment; evaluation of all available information using a strength of evidence approach; investigation of likely sources (origins) of the critical stressors.
3. The *development of strategies* to address the identified causes of impairment.

1.3.2 Approach to Management Recommendations

One of the goals of this assessment was to outline a course of action to address the key problems identified during the investigation, providing local stakeholders, the CWMTF and others with the information needed to move forward with targeted water quality improvement efforts in this watershed. It is DWQ's intent that the recommendations included in this document provide guidance that is as specific as possible given available information and the nature of the issues to be addressed. Where problems are multifaceted and have occurred over a long period of time, the state of scientific understanding may not permit all actions necessary to mitigate those impacts to be identified in advance. In such situations an iterative process of 'adaptive management' (Reckhow, 1997; USEPA, 2001a) is required, in which those committed to stream improvement efforts begin with implementation of an initial round of management actions, followed by monitoring to determine what additional measures are needed.

Protection of streams from the imposition of additional damage from future watershed development or other planned activities is a critical consideration. In the absence of such protection, efforts to restore water quality by mitigating existing impacts will often be ineffective or have only a temporary effect. These issues will be examined during the course of the study and addressed in the management recommendations.

Most management recommendations included in this document are general in nature. Ultimately, the goal is to remove Mud Creek, Clear Creek, and Bat Fork from the 303(d) list, but this report does not specify particular administrative or institutional mechanisms for implementing remedial practices. Instead, it describes the types of actions that should be taken to place these streams on the "road to improvement". It is our hope that county government and other stakeholders in the Mud Creek watershed will work cooperatively with state agencies to implement these measures.

The study did not develop TMDLs (total maximum daily loads) or pollutant loading targets. For many types of problems (e.g., most types of habitat degradation), a TMDL may not be an appropriate mechanism for initiating water quality improvement. Where specific pollutants are identified as causes of impairment, TMDLs may be appropriate and necessary if the problem is not otherwise addressed expeditiously. In any case, TMDL development is beyond the scope of this investigation.

1.3.3 Data Acquisition

While project staff made use of existing data sources during the course of the study, these were not adequate to fully address the goals of the investigation. Extensive data collection was necessary in order to develop a more adequate base of information. Biological, chemical, and toxicological data were collected primarily during 2000-2001. The types of data collected during the study included:

1. Macroinvertebrate sampling.
2. Assessment of stream habitat, morphology, and riparian zone condition.
3. Stream surveys—walking stream channels to identify potential pollution inputs and obtain a broad scale perspective on channel condition.
4. Chemical sampling of stream water quality.
5. Bioassays to assess water column toxicity.
6. Analysis of bed sediment for toxicity and chemistry.
7. Suspended sediment sampling during storm events.
8. Watershed characterization--evaluation of watershed hydrologic conditions, land use, land management activities, and potential pollution sources.

In addition, Tennessee Valley Authority's (TVA) Integrated Pollutant Source Identification (IPSI) for the Mud Creek watershed served as an important source of data on land use/cover, imperviousness, and stream channel and riparian conditions. The IPSI is a geographic database and pollutant loading model based on interpretation of low-altitude color infrared aerial photographs taken in March 2001 (TVA, 2001).

1.4 Organization of Report

This report generally addresses issues on a subwatershed level; each impaired stream and its drainage area is considered separately. Section 2 provides a detailed watershed description, including discussions of streams, land use, and potential sources of pollution. Section 3 describes the general methods used for monitoring and data analysis and the approach used to evaluate causes and sources of impairment. Sections 4 through 7 describe the monitoring results and conclusions for each subwatershed—upper Mud Creek, Bat Fork, Clear Creek and Devils Fork, and lower Mud Creek. Section 8 describes the management strategies needed to address the causes and sources of impairment identified in Sections 4 through 7.

Section 2
Description of the Mud Creek Watershed

2.1 Introduction

The Mud Creek watershed is 113 mi^2, comprising approximately one-third of Henderson County's land area. Mud Creek begins in southwest Henderson County and flows east and north through Hendersonville and to the French Broad River (Figure 2.1). It and one of its main tributaries, Bat Fork, are characterized by very low gradients and wide floodplains. Bat Fork and Devils Fork flow into the Johnson Drainage Ditch in Hendersonville before it enters Mud Creek. Both Mud Creek and Bat Fork drain a mixture of agricultural, residential, and commercial land. Clear Creek has a steeper gradient more typical of mountain streams and drains primarily agricultural and forest land. The NC Level IV Ecoregion framework developed by the Natural Resources Conservation Service (Griffith et al., 2002) mapped the bulk of the watershed in the Broad Basins ecoregion and higher ridges and slopes on the north, west, and south edges of the watershed in the Southern Crystalline Ridges and Mountains ecoregion.

This section summarizes watershed hydrography and topography, describes current and historical land use, and discusses potential pollutant sources. Much of the information in this section is from Tennessee Valley Authority's (TVA) **Integrated Pollutant Source Identification (IPSI)** for the Mud Creek watershed, which is a geographic database and pollutant loading model based on interpretation of low-altitude color infrared aerial photographs taken in March 2001 (see Section 3.1 for a more detailed description). Some of the information used in this section is from the IPSI summary document, "Mud Creek Watershed Nonpoint Source Pollution Inventory and Pollutant Load Estimates" (TVA, 2001). The IPSI database was used to calculate subwatershed-specific values on land use/cover, riparian and channel conditions, and imperviousness and to analyze relationships between IPSI and DWQ datasets.

2.2 Streams

The watershed is located within hydrologic area HA10, the mountain region, as defined by the US Geological Survey (USGS). USGS regional low flow equations for this area (Giese and Mason, 1991) predict a 7Q10 flow of approximately 37 cubic feet per second (cfs) at the mouth of Mud Creek and 17 cfs at the mouth of Clear Creek. Typical mean annual flows in this part of the state are approximately 2 cfs/mi^2.

The watershed is not currently gauged. A gauge existed on Mud Creek at US 25 from 1940 to 1955, where mean annual flow was 1.8 cfs/mi^2 and the 7Q10 was 40 cfs. Both the gauge and equation-based 7Q10s are only estimates of current conditions; further urbanization of the watershed since 1955 has occurred, likely lowering the actual 7Q10 by decreasing the amount of groundwater infiltration, and the USGS equations are designed for non-urban areas.

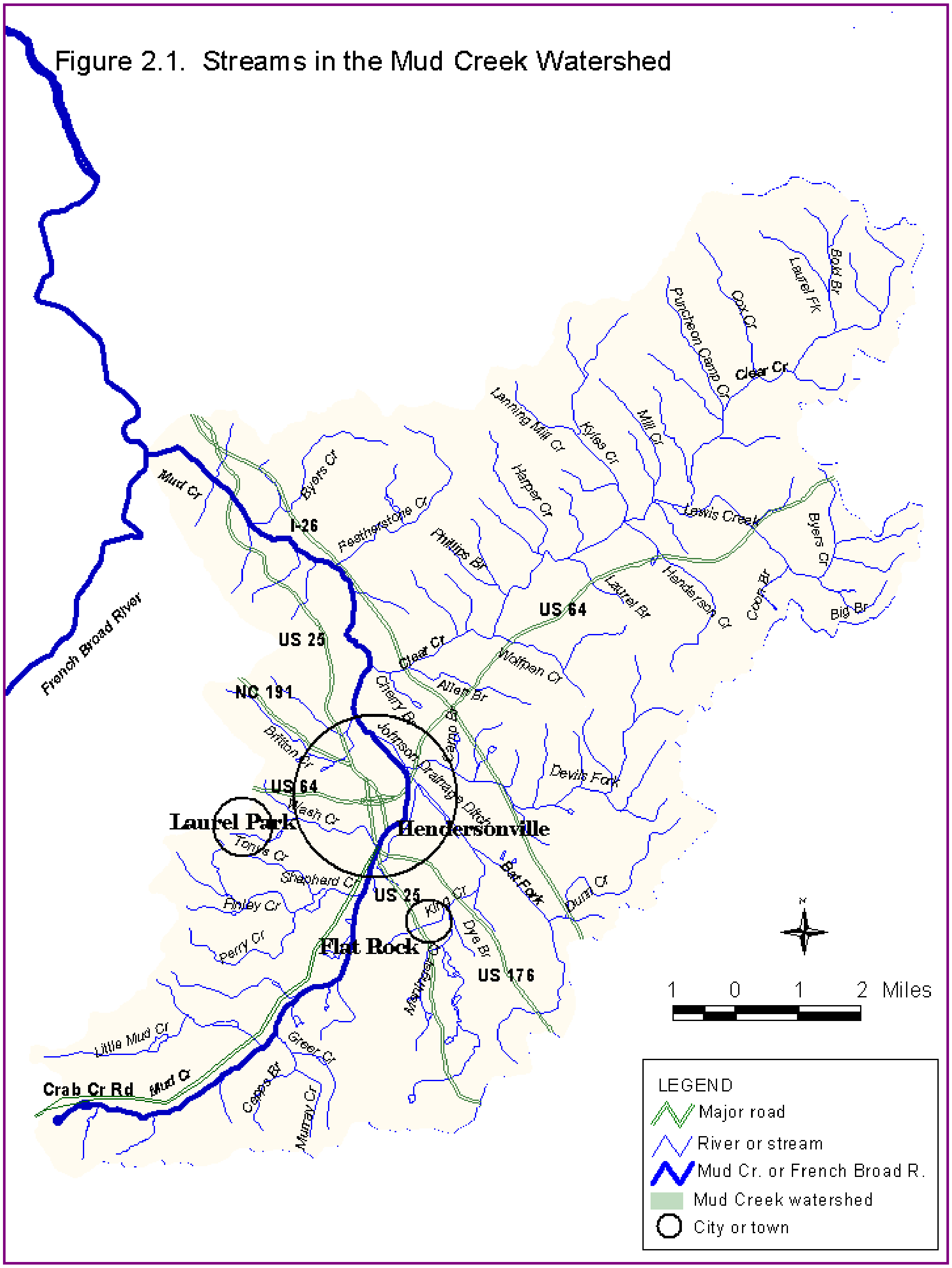


Figure 2.1. Streams in the Mud Creek Watershed

Based on data for 1949 to 2001 (excluding 1963 due to incomplete data), Hendersonville receives an average of 56 inches of rainfall annually (State Climate Office of NC at NC State University). Western North Carolina has been in a drought since mid-1998, and rainfall at Hendersonville was 84%, 75%, and 76% of the annual average for years 1999, 2000, and 2001, respectively.

Most streams in the Mud Creek watershed are classified as C, although there are some tributaries that are classified as B, usually due to run-of-the-river lakes on the streams. The upper part of Clear Creek and some of its tributaries are classified as Trout waters; a Trout water classification does not signify the presence of trout in a stream but is intended to protect any trout present with higher water quality standards for dissolved oxygen, temperature, and turbidity.

For purposes of this report this watershed is divided into five subwatersheds—upper Mud Creek (upstream of Erkwood Rd.), Clear Creek, Devils Fork, Bat Fork, and lower Mud Creek (downstream of Erkwood Rd.) (Figure 2.2). Gradient is characterized in relative terms (e.g., low or moderate) and not based on any fluvial geomorphological classification.

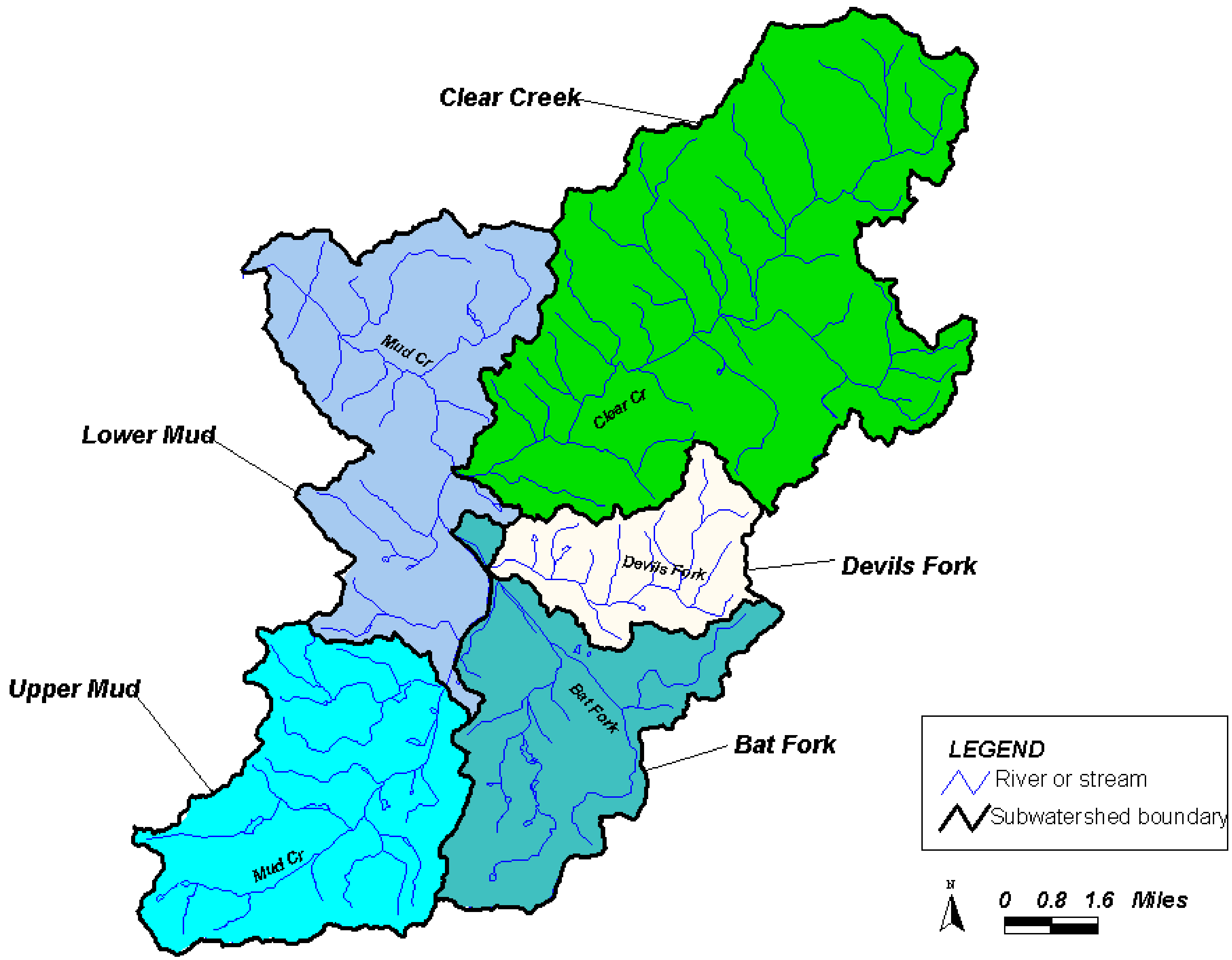
Upper Mud Creek. The upper Mud Creek subwatershed is 20.5 mi^2 and part of USGS 14-digit hydrologic unit 06010105030020. Mud Creek headwaters are at 2,800 ft msl. Mud Creek flows through a very wide valley (100-yr floodplain: 800-1,500 ft wide) and has a gradient atypically low for the mountains—in its upper section, it drops 34 ft/mi, but its lower section (from Greer Creek to Erkwood Rd.) has a gradient of just 7 ft/mi. Tributaries to the south that drain Pinnacle Mountain are higher gradient, and tributaries from the rolling hills to the west of Mud Creek are of moderate gradient.

The IPSI estimated the extent of stream channelization in the Mud Creek watershed. Determination of channelization was conservative; only obvious signs of channelization were used (long straight channels or spoil along banks), so streams that are recovering from older channelization may not have been identified as channelized. According to the IPSI, the upper Mud Creek subwatershed has the least degree of stream channel modification. *Only 14% of its stream miles are channelized* (Table 2.1). Most of the channelized stream miles are on the Mud Creek mainstem or in tributaries as they enter the wide Mud Creek floodplain.

The IPSI also characterized the width and vegetation type and condition of riparian buffers for a set of streams that were considered perennial by aerial photograph interpretation. These "perennial" streams are a subset of streams (only 44% of the total stream miles identified by the IPSI) that have larger drainage areas and are an underestimate of perennial stream miles as defined on US Geological Survey 1:24,000 scale topographic maps. Headwater streams were generally not considered perennial. For this report, adequate buffers were defined as those with woody vegetation with at least 66% crown cover and a width of ≥ 30 ft. *Of these "perennial" streams, only 12% of total stream miles have adequate buffers on both banks in the upper Mud Creek subwatershed. Along the Mud Creek mainstem, only 1% of its perennial length has adequate buffers*. Much of the buffered and non-channelized sections of stream are along the southern ridge area or in the Little Mud Creek drainage, where the land is primarily forested.

Clear Creek. The Clear Creek subwatershed has the largest drainage area (44.5 mi^2) of the Mud Creek watershed and comprises USGS 14-digit hydrologic unit 06010105030040. Clear Creek

Figure 2.2. Subwatersheds in the Mud Creek Watershed



(18 mi) flows through a rolling valley and has moderate gradient, falling approximately 46 ft/mi, from its headwaters at 2,900 ft msl to its confluence with Mud Creek at 2,070 ft msl. High gradient tributaries drain the steeper land to the north of Clear Creek, and lower gradient tributaries drain gently rolling land to the east and south of Clear Creek.

The IPSI identified 23% of streams in the Clear Creek subwatershed as channelized. Many of these streams are concentrated in certain areas; 26% of the Clear Creek mainstem is channelized, and 43% of the stream miles in the Lewis Creek drainage are channelized. Few streams in the forested northern headwaters are channelized.

Only 11% of total stream miles have adequate buffers on both banks in the Clear Creek subwatershed. The Lewis Creek drainage has no "perennial" stream miles with adequate buffers on both banks. In general, adequate buffers are present along upper sections of the tributaries that drain the forested northern ridge. In the lower gradient areas that are primarily in agriculture, there are small stream sections that have adequate buffers in small forested patches.

Devils Fork. The Devils Fork subwatershed is characterized by rolling hills, and its 8.6 mi^2 area is within USGS 14-digit hydrologic unit 06010105030020. Devils Fork is 6 mi in length and has moderate gradient (30 ft/mi). There are no named tributaries.

According to the IPSI, 44% of the streams in the Devils Fork subwatershed are channelized, and only 2% of the "perennial" streams have adequate buffers. The high degree of stream channel and riparian vegetation modification corresponds with the highly agricultural nature of this subwatershed.

Table 2.1 Channelization and Buffers in the Mud Creek Watershed[1]

	Percentage of Stream Miles	
Subwatershed	**Channelized Streams (%)**	**Adequate Buffers on Both Banks[2] (%)**
Upper Mud Creek	14	12
Clear Creek	23	11
Devils Fork	44	2
Bat Fork	45	15
Lower Mud Creek	23	9

1 Based on TVA analysis of aerial photography.
2 Determined for a subset of streams (44% of total) that have a larger drainage area; adequate buffers are those with ≥ 30 ft of woody vegetation with ≥ 66% crown cover.

Bat Fork. The Bat Fork subwatershed is 16.4 mi^2 and part of USGS 14-digit hydrologic unit 06010105030020. The southern edge is defined by a high ridge (2,300 to 2,900 ft msl), where Bat Fork starts. This creek is of moderate gradient (approximately 90 ft/mi) in its first 1.5 mi, but then drops to a low gradient system (20 ft/mi, from US 176 to confluence with Johnson Drainage Ditch) with a wide floodplain (100-yr floodplain: 100-1500 ft wide) for its downstream 4.9 mi. (Note: Bat Fork stream mileage used in this discussion is from Geographic Information Systems data generated by the NC Center for Geographic Information Analysis, which measures the creek's length as 6.4 miles. The 2002 303(d) list identifies Bat Fork's entire length as 4.8 miles.)

IPSI results indicate a high degree of stream channel and riparian modification in the Bat Fork subwatershed. *Forty-five percent of stream miles have been channelized, and 15% of "perennial" stream miles have adequate buffers. The Bat Fork mainstem is extremely modified, without any adequate stream buffers and with 65% of its length channelized.*

Lower Mud Creek. The lower Mud Creek subwatershed is 22.8 mi^2 and comprises the USGS 14-digit hydrologic unit 06010105030030 and part of unit 06010105030020. It starts below the confluence of Mud Creek and Shepherd Creek at Erkwood Rd. and includes the more suburban and urban drainages around Hendersonville and Laurel Park. It is generally a low gradient area, defined by low ridges and a few small mountains. As in the upper Mud Creek subwatershed, Mud Creek is a very low gradient stream, dropping 5 ft/mi. Its 100-yr floodplain is up to 4,000 ft wide. In this subwatershed, Devils Fork and Bat Fork enter Mud Creek via the Johnson Drainage Ditch in Hendersonville, and Clear Creek flows into Mud Creek just upstream of the Hendersonville wastewater treatment plant. Tributaries to the north and west begin on ridges and have higher gradient.

IPSI analysis classified 23% of stream miles as channelized and 9% of "perennial" stream miles as having an adequate buffer. Only 4% of the Mud Creek mainstem has adequate buffers. The IPSI identified very little of the Mud Creek mainstem as channelized; but historical records including old topographical and property maps indicate that most of Mud Creek has been channelized in the last 150 years.

2.3 Geology and Soils

The Mud Creek watershed is underlain primarily by Henderson gneiss of the Inner Piedmont Belt. Three general soil associations comprise the majority of the Mud Creek watershed soil types—1) the Codurus-Toxaway-Rosman association, which are floodplain soils and consist of well drained to very poorly drained soils that have loamy and sandy subsoils; 2) the Hayesville-Bradson association, which are soils on ridges and stream terraces and consist of gently sloping to moderately steep, well drained soils that have loamy and clayey subsoil; and 3) the Evard-Edneyville-Ashe association, which are soils occurring on mountain ridge tops and side slopes and consist of sloping to very steep, well drained and somewhat excessively drained soils that have loamy subsoils (USDA, 1980).

Hydric soils, or soils which are periodically saturated or flooded (often defined as wetland soils), figure prominently in floodplain areas, especially in the Bat Fork, upper Mud Creek, the southern part of lower Mud Creek, and Devils Fork subwatersheds (Figure 2.3). Four percent of soils (4.1 mi^2) in the watershed are hydric, and another seven percent (8.3 mi^2) have hydric inclusions. Many of these soils are actively drained for agriculture, and a small proportion has wetland vegetation. According to the IPSI, there are 0.9 mi^2 (580 acres) of wetlands (defined by the presence of wetland vegetation) in the watershed, located mostly along Mud Creek in and downstream of Hendersonville (see Section 2.4). Only eight percent of hydric soils and four percent of soils with hydric inclusions presently have wetland vegetation.

2.4 Land Use in the Watershed

2.4.1 History

Much of the following historical information comes from *A Partial History of Henderson County* (Fain, 1980) and *From the Banks of the Oklawaha* (Fitzsimons, 1976). The area now known as Henderson County (of which the Mud Creek watershed comprises 30%) was once a hunting ground for the Cherokee Indians. Europeans settlement of the area began in the late 1700s. Although it has been an agricultural area since the 1800s, it has had increasing popularity as a retirement community, and recent growth has occurred at a high rate. In 1850, Henderson County had a population of 6,483; in 1970, 42,804; and in 2001, 91,267.

<u>Agriculture</u>
Agriculture has always been a driving force in the economy and growth of Henderson County. The wide, fertile floodplains and valleys have encouraged the agricultural growth of the area. Early European settlers were subsistence farmers, but once a railroad began serving the area, commercial agriculture became more important. Notable crops in the 1800s were corn and apples; livestock farming (dairy, hogs, sheep, and chickens) was also an important commercial venture.

In 1910 the NC Department of Agriculture declared the Appalachians to be the best area in the country to grow apples and peaches. Apples have been farmed in Henderson County since the early 1800s and continue to be a significant agricultural endeavor. Apple farming increased in popularity until the mid-1900s. In 1975, apples (followed by row crop vegetables and dairy) generated more income than any other agricultural product in the county. However, a decline in apple growing began in the 1980s; the 1987 and 1997 US Department of Agriculture censuses reported 10,684 acres and 7,302 acres in orchards, respectively. Much of this decline is attributed to foreign market competition driving down apple and apple concentrate prices.

On the whole, agriculture is declining in Henderson County (Table 2.2). There was a loss of 25% of farmland between 1987 and 1997, and much of this land is being converted to residential land. Agricultural products are changing, as well, with sod farms, tomatoes, other vegetables, and tobacco replacing the orchards, corn, and dairies.

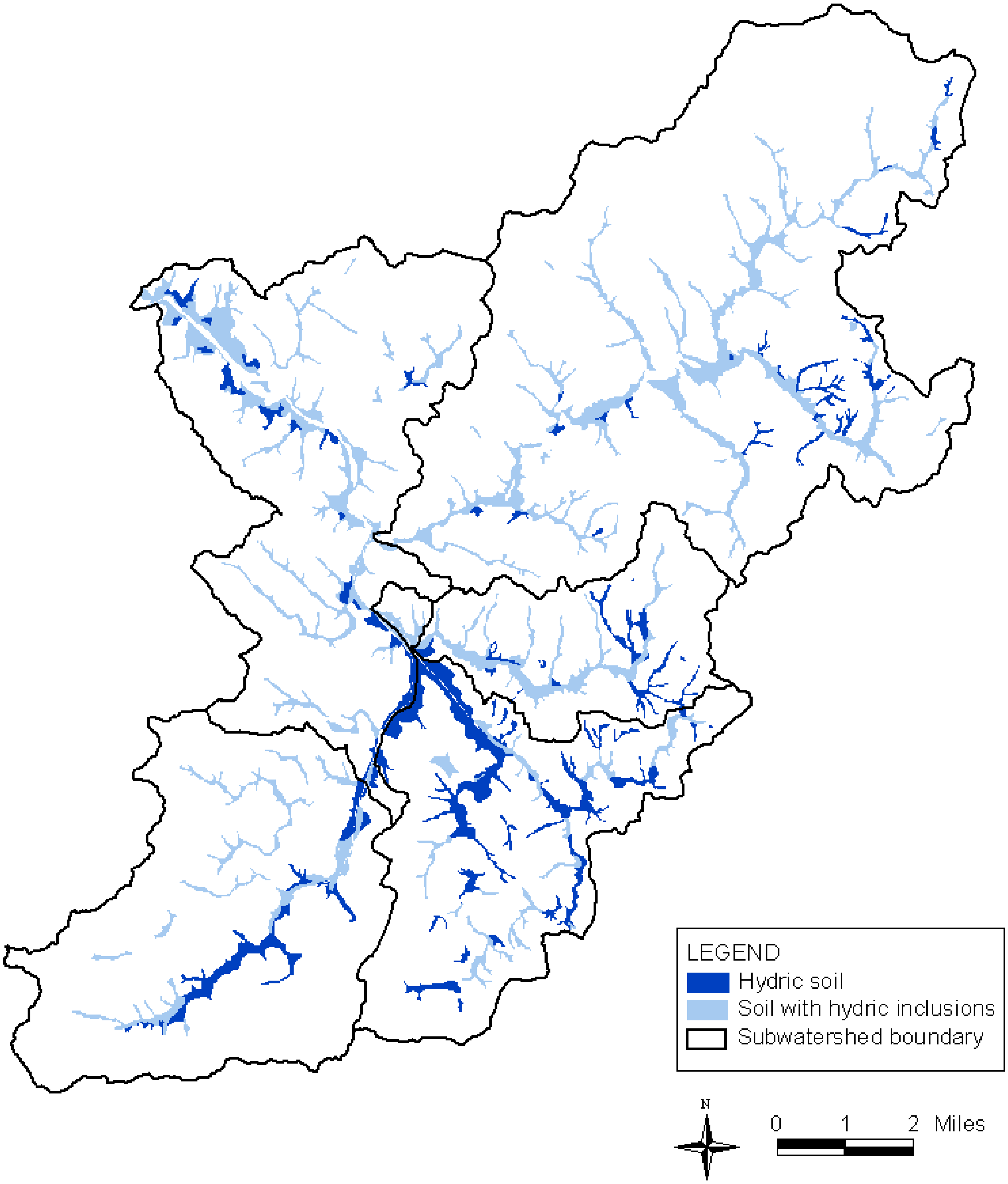
Table 2.2 Recent Trends in Agriculture in Henderson County[1]

	Total Acreage			**Total Number of Animals**	
Year	Farmland	Apples	Grain/Seed Corn	Dairy	Beef
1987	59,232	10,684	5,071	3,663	1,810
1997	44,511	7,302	2,130	2,781	2,233

[1] Source: USDA Census of Agriculture.

<u>Industry, Timber, and Mining</u>
Among the first trade businesses were textiles, hosiery, yarns, canning, and a mission furniture factory. Many businesses were set up to support the agricultural resources of the county.

Figure 2.3. Hydric Soils in the Mud Creek Watershed



Vegetable packing/processing, manufacturing, retail trade, and service industries account for the majority of the labor force today. Presently, the largest industries in the county are General Electric, Kimberly-Clark (sanitary paper products), Coats North America (thread), and two porcelain electrical supplies manufacturers--Selee Corporation and Kyocera Industrial Ceramics.

Nearly all of the land in Henderson County has been logged. After the Hendersonville-Brevard Railroad was completed in 1894, large-scale logging occurred until the 1930s. Presently, rock quarries are the only notable mining operations in the Mud Creek watershed.

Floodplain Conversion and Channelization

Significant channelization and floodplain alteration occurred well over 100 years ago on larger streams in the Mud Creek watershed, including Mud Creek, Bat Fork, and Devils Fork. Wide fertile floodplains that once served to store floodwaters were drained and diked to allow farming. Mud Creek and its tributaries with wide floodplains were very sinuous streams, often lined by wetlands; examination of historical topographic and parcel maps revealed that large-scale channelization of Mud Creek occurred between 1840 and 1890.

Flooding has been a persistent issue in Henderson County, especially within the Mud Creek watershed. Commercial and residential development has occurred in the floodplain; much of Hendersonville is built in the floodplain, leaving it susceptible to flooding. Major floods of 1916, 1940, and 1964 caused much concern, leading to a number of stream channelization and dredging projects aimed at minimizing flooding problems.

2.4.2 Present Day Land Use—IPSI Analysis

Based on aerial photographs taken in March 2001, TVA's Integrated Pollutant Source Identification (IPSI) determined that 45 percent of the Mud Creek watershed is forest, 25 percent is residential, commercial or industrial, and 23 percent is agricultural (Table 2.2 and Figures 2.4 through 2.8).

Most of the forested land is along the northern and southern ridges that border the watershed, and accordingly, the Clear Creek and upper and lower Mud Creek subwatersheds have 39-60 percent of their land use in forest. However, these areas are desirable for homesites, and new development (individual homesites and planned communities) is occurring in these steeper areas. The southern ridge of the Bat Fork subwatershed, for example, is a patchwork of homesites that radiate from the Kenmure Golf Course.

Agricultural land (row crops, orchards, pasture) is a significant portion of the watershed, accounting for more than one-fifth of each subwatershed except those of upper and lower Mud Creek. Apple orchards are prominent in the valleys and on gentle slopes of the Clear Creek and Devils Fork subwatersheds and the Dunn Creek area of the Bat Fork subwatershed. Stream bottoms that are now planted in orchards were farmed intensively in row crops (beans, cabbage) in the 1950s to 1970s. Pasture, often for beef cattle, is sited along stream valleys and accounts for at least one-half of the agricultural land use in all subwatersheds. It is particularly notable along the mainstems of Clear and Mud Creeks, but also occurs along many tributaries. Although there are many cattle farms in the watershed, none are large enough to be permitted by DWQ through the National Pollutant Discharge Elimination System (NPDES) program. Row crops are usually in flat floodplain areas, and corn and market vegetables (e.g., squash, beans, tomatoes, and peppers) are common.

Residential land accounts for almost a fourth of land in all subwatersheds except that of Clear Creek. Residential land spreads from Hendersonville west to Laurel Park and south to Flat Rock. North of Little Mud Creek, there is a broad swath of residential land along the Mud Creek corridor. Although residential land is not as predominant in the Clear Creek subwatershed, a shift from agricultural to residential land is apparent. 1.6 mi^2 of old apple orchard is no longer in production and in transition to other uses (often eventually residential); this area is almost 20 percent of the total area that is currently in apple production or in transition from apple production.

Commercial and industrial land is concentrated in and around Hendersonville, following the US 64, I-26, US 25, and US 176 road corridors. Most of it is in valleys along Mud Creek, lower Devils Fork, and Bat Fork.

There are several golf courses in the watershed, including Kenmure Golf Course in the upper Bat Fork subwatershed, Highland Lake Golf Club on King Creek, Crooked Creek Golf Club along upper Mud Creek, Champion Hills Country Club on Perry's Creek, and Hendersonville Country Club on Tony's Creek (both Perry’s and Tony’s Creeks flow into Shepherd Creek which flows into lower Mud Creek).

Impervious cover (areas such as rooftops, roads, and parking lots that prevent infiltration of precipitation into the soil) was also analyzed by the IPSI; TVA calculated percent impervious cover for each land use/cover polygon and percent imperviousness for roads not accounted for in each polygon. Only artificial cover was considered impervious; actual imperviousness of the watershed is likely underestimated because urban soils such as athletic fields and lawns are compacted and may act as impervious surfaces (Schueler, 2000a). A substantial body of evidence indicates that as imperviousness of a watershed increases, stream integrity decreases—biodiversity decreases, channel instability increases, and in-stream habitat is degraded (Schueler, 1994). The Center for Watershed Protection (2001) presents three watershed vulnerability categories for first to third order streams based on impervious cover:

1) Sensitive stream. 0-10 % impervious cover. Stable stream channel, good habitat, diverse biological communities.
2) Impacted stream. 11-25% impervious cover. Stream channels erode and widen, banks unstable. Habitat declines. Sensitive biota disappear.
3) Severely impacted stream. >26% impervious cover. Stream channel highly unstable. Habitat very degraded. Only pollution tolerant biota present.

These are general thresholds; in actuality, stream impacts from imperviousness occur along a continuum, generally worsening with increasing imperviousness. However, the impacts of urbanization not only depend on imperviousness, but also on stormwater management systems, development styles, and drainage types (Bledsoe, 2001). Actual impacts to streams also depend on stream type (e.g., gradient, substrate type) and watershed characteristics (e.g., size, land use history).

Table 2.3 Land Use/Cover in the Mud Creek Watershed, as Determined by TVA's Integrated Pollutant Source Identification

Land Use Class[1]	Upper Mud		Clear		Devils Fork		Bat Fork		Lower Mud		Total Area	
	Sq. Miles	%	Sq. Miles	%	Sq. Miles	%	Sq. Miles	%	Sq. Miles	%	Sq. Miles	%
Forest	12.4	60	22.1	50	1.7	20	5.1	31	8.9	39	50.2	45
Wetland	0.0	0	0.1	0	0.1	1	0.2	1	0.6	3	0.9	1
Transitional area	0.2	1	1.9	4	0.4	5	0.7	5	0.6	3	4.0	4
Open maintained	0.5	2	0.2	0	0.1	2	0.5	3	0.5	2	1.9	2
Orchard	0.0	0	5.6	12	1.1	13	0.7	4	0.0	0	7.4	7
Row crop	0.3	2	1.3	3	0.7	9	0.7	4	0.5	2	3.6	3
Pasture	2.2	11	6.5	15	1.9	22	2.4	15	2.0	9	15.0	13
Residential	4.4	21	5.4	12	2.0	24	3.9	24	6.9	31	22.6	20
Commercial/industrial	0.2	1	0.9	2	0.3	4	1.7	10	2.1	9	5.2	5
Disturbed	0.1	0	0.2	0	0.0	0	0.2	1	0.2	1	0.7	1
Other	0.2	1	0.2	1	0.1	1	0.2	1	0.3	1	1.0	1
Total	20.6		44.5		8.6		16.4		22.6		112.6	

[1] "Transitional area" is shrub/old field vegetation or unmanaged orchard.
"Open maintained" is golf course, athletic field, cemetery, transmission or highway right-of-way, or airport grassed runway.
"Disturbed" is clear cut forest, mining, construction, or other disturbed area.

Table 2.3 Percent Imperviousness in Mud Creek Subwatersheds

Subwatershed	Percent Imperviousness
Upper Mud Creek	8%
Clear Creek	6%
Devils Fork	10%
Bat Fork	15%
Lower Mud Creek	17%

Using these general categories for comparison, Bat Fork and lower Mud Creek fall within the "impacted stream" category (Table 2.3). However, when percent imperviousness is determined for smaller drainage areas, drainages in the Hendersonville and Laurel Park area approach or exceed the severely impacted stream category, including Wash Creek (32%), Brittain Creek (23%), drainages along the Mud Creek mainstem (22%, 43%, and 27%), and lower Bat Fork (36%) (Figure 2.9). Clear Creek and upper Mud Creek drainages have relatively low imperviousness, reflecting the lower amount of development in these primarily forested and agricultural areas.

2.5 Sources of Pollution

2.5.1 Wastewater Discharges

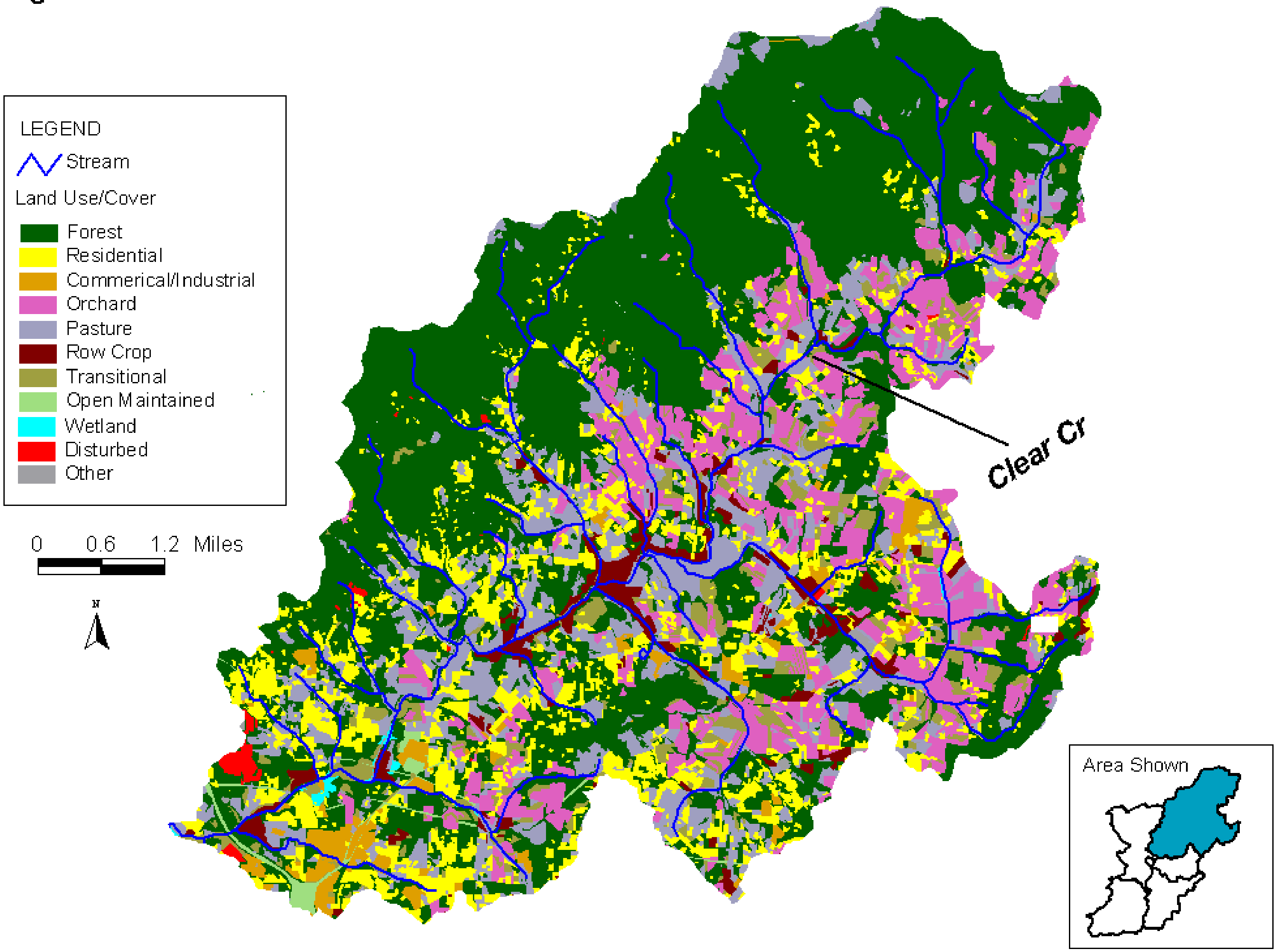
Twenty-four National Pollutant Discharge Elimination System (NPDES) permitted facilities were active in the Mud Creek watershed in 2000 and 2001 (Figure 2.10, Table 2.4). Several facilities became inactive during this period and are now diverting their waste to the Hendersonville wastewater treatment plant (WWTP). A number of facilities were non-compliant and were issued notices of violation (NOV) during this time (Table 2.5).

The largest discharger is the City of Hendersonville's WWTP, which discharges to lower Mud Creek. This facility treats both domestic and industrial wastewaters from parts of Laurel Park, the Town of Flat Rock, the City of Hendersonville, and greater Henderson County. Until March of 2002 the plant discharged its effluent into Mud Creek upstream of Berkeley Rd. (SR 1508) and upstream of the confluence with Clear Creek, with a permit to discharge up to a monthly average of 3.2 million gallons per day (mgd). In March of 2002 construction was completed on a new facility, permitted to discharge up to a monthly average of 4.8 mgd. This new plant's discharge is below the confluence of Mud and Clear Creeks.

The old facility was required to perform whole effluent toxicity tests, which expose test organisms to effluent over 7 days, on a quarterly basis using an in-stream waste concentration of 22%. The plant has passed all such tests since February 1998 except for that of the third quarter in 2001. This plant was operating under a Special Order of Consent (SOC), which suspended or lessened effluent concentration limitations while still requiring all parameters to be monitored.

General Electric (GE) discharged treated waste from its luminaire manufacturing operation from 1974 to 1995 to Bat Fork. Now, all of its process wastewater is sent to the Hendersonville WWTP. From 1997-2000, GE discharged treated contaminated groundwater to Bat Fork (see Section 2.5.2 for discussion).

Figure 2.4. Land Use/Cover in the Clear Creek Subwatershed



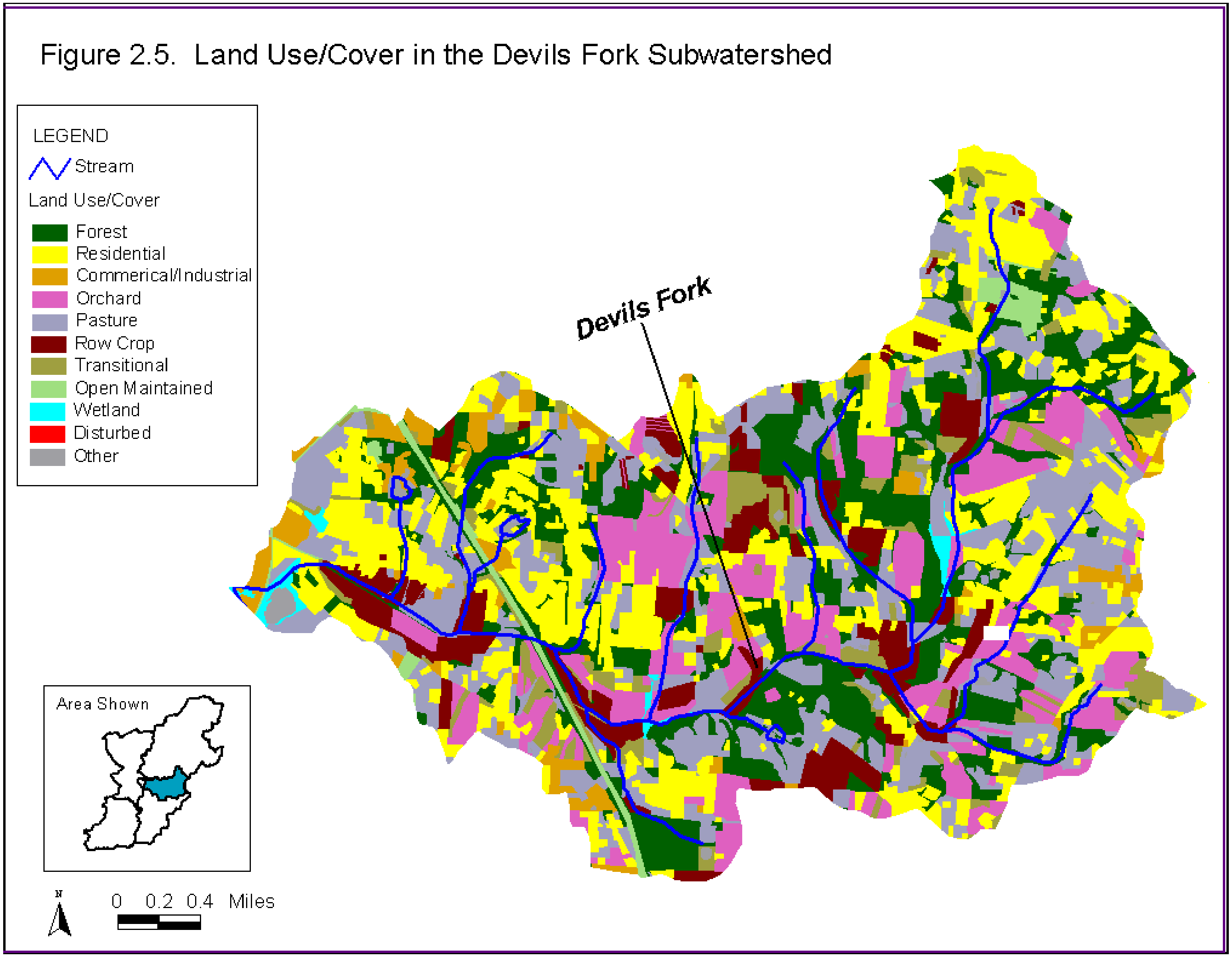


Figure 2.5. Land Use/Cover in the Devils Fork Subwatershed
LEGEND
Stream
Land Use/Cover
Forest
Residential
Commerical/Industrial
Orchard
Pasture
Row Crop
Transitional
Open Maintained
Wetland
Disturbed
Other
Devils Fork
Area Shown
N
0 0.2 0.4 Miles

Figure 2.6. Land Use/Cover in the Bat Fork Subwatershed

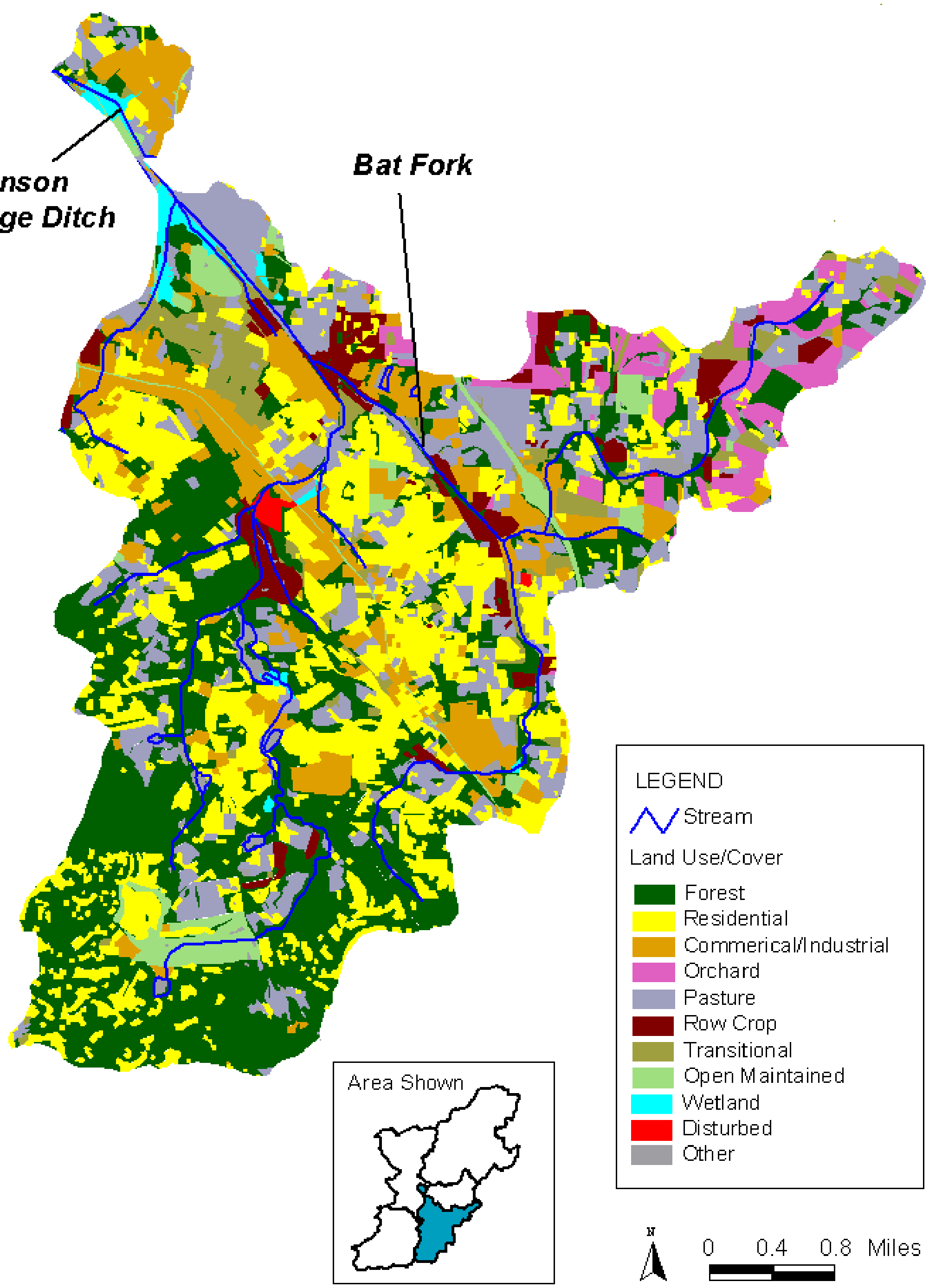


Figure 2.7. Land Use/Cover in the Upper Mud Creek Subwatershed

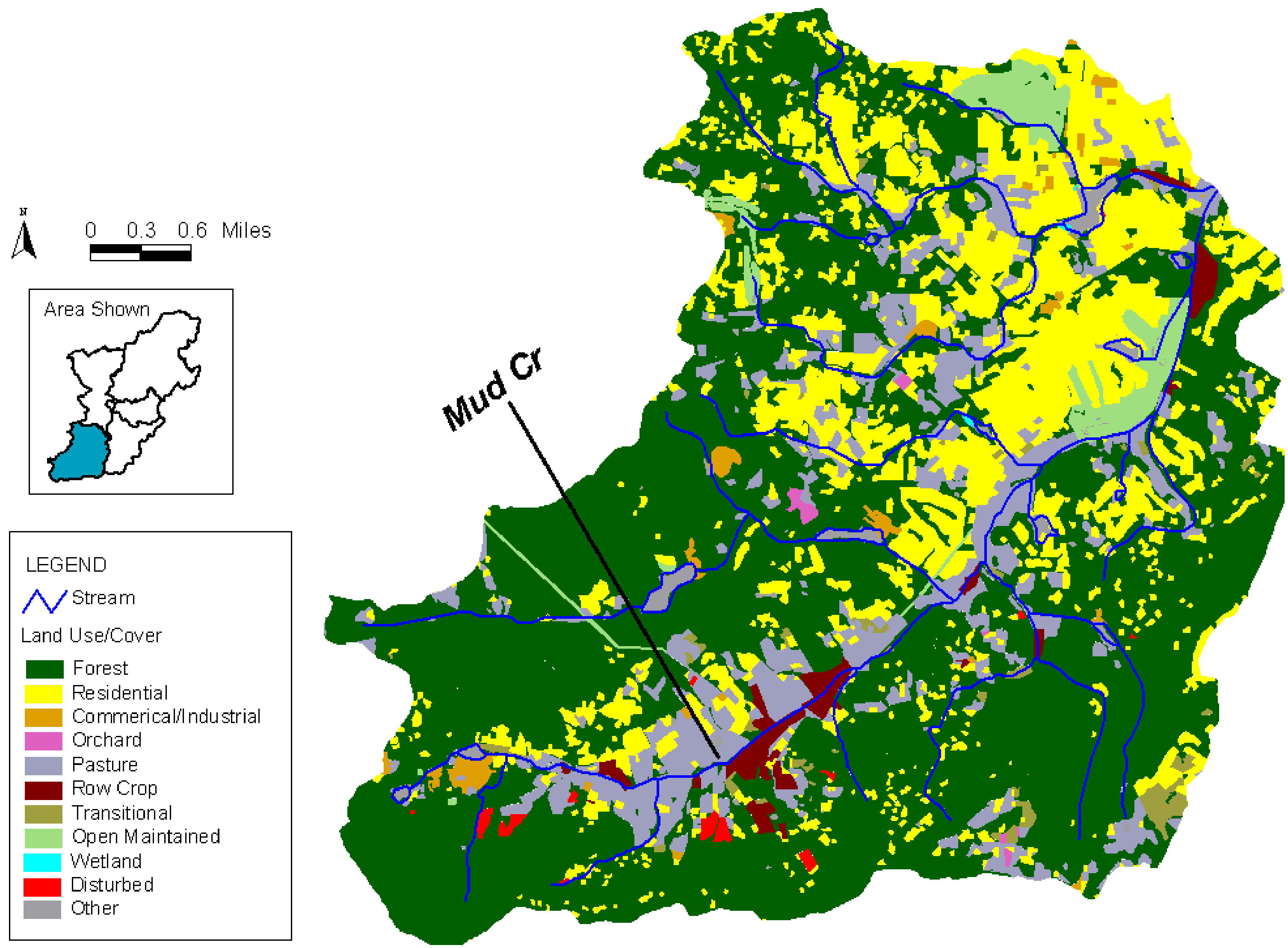


Figure 2.8. Land Use/Cover in the Lower Mud Creek Subwatershed

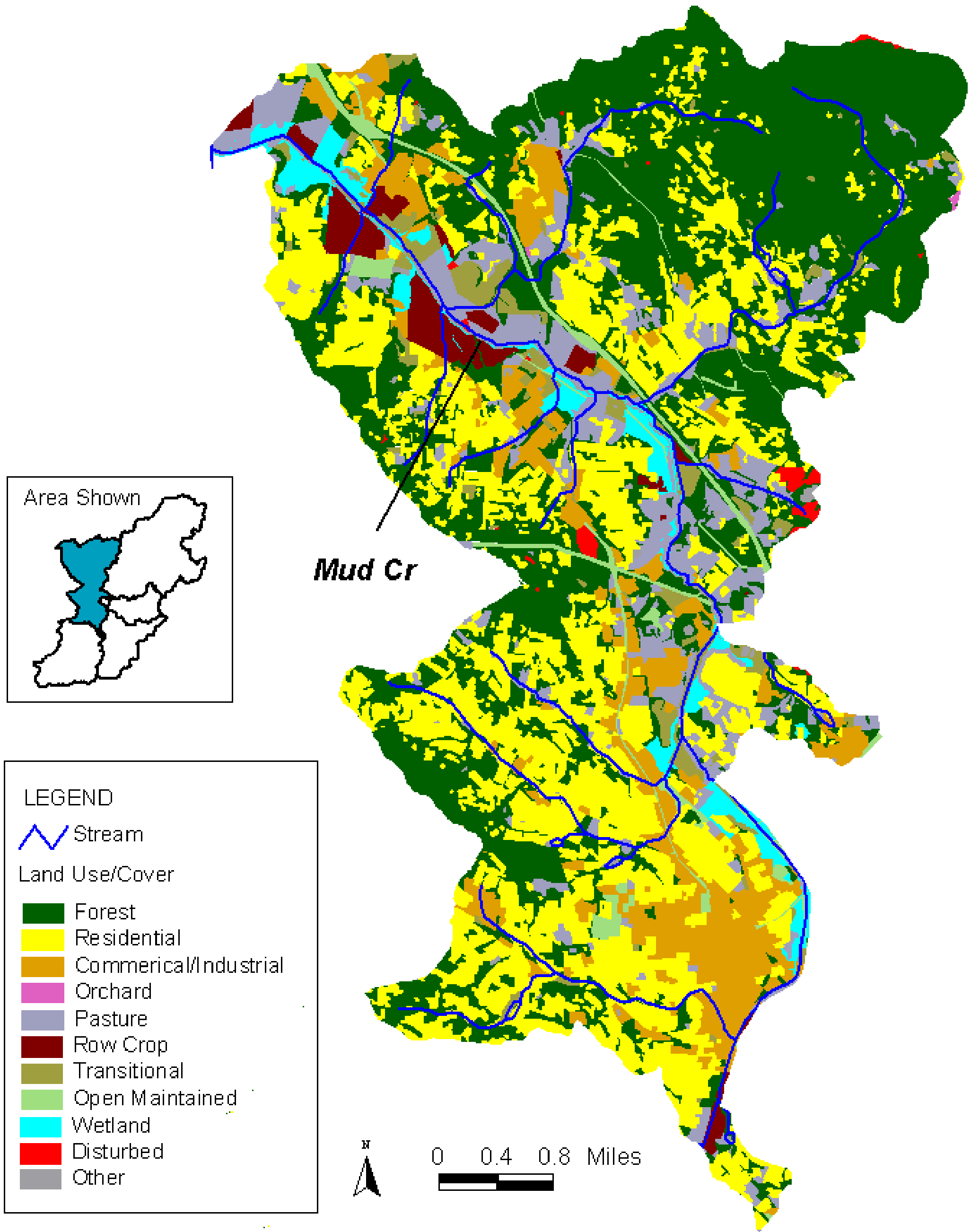


Figure 2.9. Imperviousness in Drainages of the Mud Creek Watershed

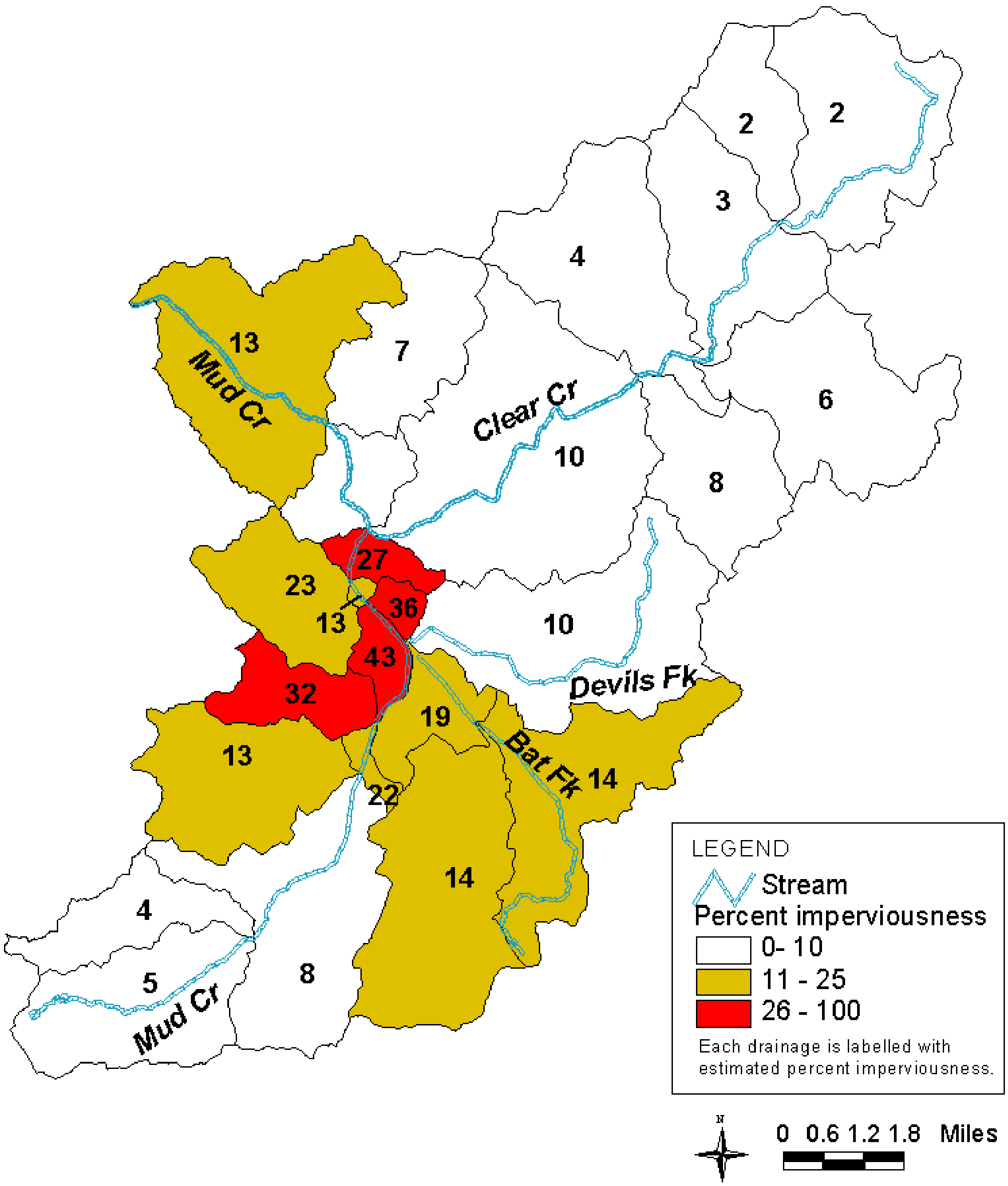


Table 2.4 NPDES Permitted Facilities in the Mud Creek Watershed in 2000 and 2001

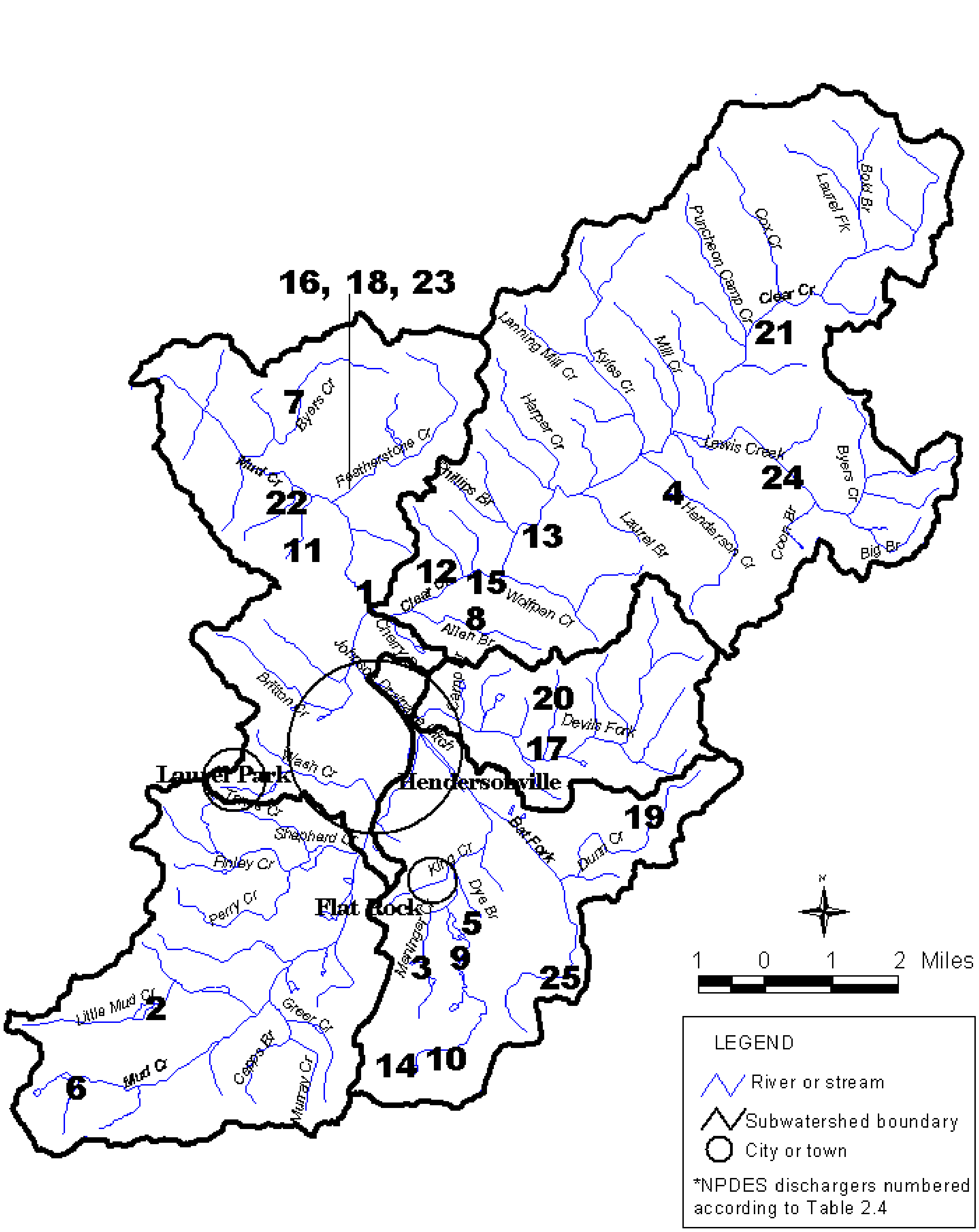
Permit	Number in Fig 2.10	Facility	Flow (gpd)	Receiving Stream	Inactive Date
NC0025534	1	Hendersonville	3,200,000	Mud Creek	
NC0024431	2	Kanuga Conferences Incorporated	35,000	Little Mud Creek (Kanuga & Wolf Lakes)	
NC0032140	3	Flat Rock Playhouse	10,000	Meninger Creek	
NC0033430	4	Camp Judaea	30,000	Henderson Creek	
NC0034401	5	Highland Lake Inn & Conf Center	10,000	King Creek	9/16/01
NC0036251	6	Blue Star Camps Incorporated	60,000	Mud Creek	
NC0036641	7	Fletcher Academy	100,000	Byers Creek	
NC0037176	8	Bon Worth Incorporated	6,000	Allen Branch	
NC0039721	9	Bonclarken Assembly	70,000	King Creek	9/30/00
NC0056928	10	Kenmure/Overlook Drive	25,200	King Creek	11/15/01
NC0066362	11	Benson Apartments	8,000	Mud Creek	
NC0068799	12	Greystone Subdivision	21,700	Clear Creek	
NC0069370	13	Emeritus Corporation DBA Pine Park	25,000	Clear Creek	
NC0069949	14	Kenmure/Forest View	21,000	King Creek	11/15/01
NC0071862	15	Magnolia Place	22,000	Clear Creek	
NC0071897	16	Henderson's Assisted Living	7,000	Featherstone Creek	
NC0073393	17	Dana Hill Corporation	30,000	Devils Fork	
NC0074110	18	Mountain View Assisted Living	5,000	Featherstone Creek	
NC0074136	19	Lakewood RV Resort	15,000	Dunn Creek	
NC0075647	20	Hidden Gap Mobile Home Park	20,000	Devils Fork	not in operation
NC0076082	21	Bear Wallow Valley Mobile Home Park	10,000	Clear Creek	
NC0079251	22	Clement Pappas	90,000	Mud Creek	
NC0083313	23	Brookside Village Association	5,000	Featherstone Creek	
NC0086070	24	Justice Academy	30,000	Lewis Creek	
NC0000507	25	GE Lighting Systems Incorporated	500,000	Bat Fork	10/30/00

Table 2.5 Non-Compliant NPDES Facilities in 2000-2001

Facilitiy	Date	Reason for Noncompliance/Violation
Brookside Village Association	Nov-01	Missing parameter SC
Camp Blue Star	Jul-00	Permit limit exceeded TRC
	Aug-00	Permit limit exceeded TRC
	Nov-01	Missing parameters
Camp Judaea	Nov-01	Missing parameters
City of Hendersonville	Apr-00	Permit limits exceeded BOD, Flow, DO,TSS
	Feb-01	Permit limit exceeded TSS
	Mar-01	Permit limit exceeded TSS
	Apr-01	Permit limits exceeded SS, TSS, DO
	Aug-01	Flow measurement
	Sep-01	Frequency of monitoring all parameters
	Nov-01	Missing pH, Turbidity analysis
	Dec-01	Flow exceedance, 12 missing parameters
Dana Hill Corporation	Jan-01	Permit limit exceeded Ammonia
	Apr-01	Permit limit exceeded Ammonia
	Sep-01	Permit limits exceeded BOD, Ammonia, TSS/missing COD, DO,TN, TP,SS analysis
	Nov-01	Permit limit exceeded Ammonia
Flat Rock Playhouse	Sep-01	Missing COD, DO, TN, TP, SS analysis
General Electric	Apr-00	Permit limits exceeded Copper, Zinc, TSS
	Mar-01	Permit limit exceeded Copper, Zinc
	Sep-01	Frequency of monitoring all parameters and missing beryllium analysis
Greystone Subdivision	Nov-01	Missing TN and TP analysis
Hendersons Rest Home	Nov-01	DO sample type Violation
Kanuga Conference Center	Nov-01	Permit limits exceeded BOD, TSS, Ammonia
	Dec-01	Permit limit exceeded BOD/missing COD, SS, TSS analysis
Lakewood RV Resort	Jun-00	Permit limit exceeded TSS
Northland Cranberries/ Clement Pappas	Sep-01	Missing DO analysis
	Oct-01	Flow measurement, parameters missing DO, SC
	Nov-01	Flow measurement
	Dec-01	Missing parameters

[1] DO = dissolved oxygen; COD = chemical oxygen demand; TN = total nitrogen; TP = total phosphorus; SS = settleable solids; TSS = total suspended solids; BOD = biochemical oxygen demand; TRC = total residual chlorine; SC = specific conductance.

Figure 2.10 NPDES Permitted Discharges in the Mud Creek Watershed*



2.5.2 Nonpoint Source Inputs

Recent Development

Development associated with home sites and commercial ventures has resulted in increased sedimentation in creeks in the watershed. In the rapidly growing Hendersonville area and I-26 corridor, commercial construction sites often expose a large amount of bare soil (Figure 2.11). Because erosion control measures are often inadequate, many of these sites serve as sediment sources for area creeks. Construction for both house sites and roads in residential developments also serve as sediment sources for streams, especially in higher slope areas where it is more difficult to stabilize disturbed soil. After construction, any slopes that have been cut into hillsides and have not been stabilized with vegetation continue to erode. The IPSI identified 68 miles of road with eroding banks in the Mud Creek watershed. Once in place, gravel and dirt roads in the steep areas of this watershed continue to be a significant source of sediment during storms (Figure 2.12). According to the IPSI, a high proportion (34% or 272 miles) of the roads in the watershed are unpaved.

Figure 2.11 Site prepared for commercial development in the Mud Creek watershed.

Figure 2.12 Runoff from gravel driveway in the upper Mud Creek watershed.

When construction is sited near a creek, the stream banks are often cleared of vegetation, exposing bare banks and promoting future bank instability (Figure 2.13). Sometimes streams themselves may be dredged and bottom habitat disturbed.

Urban inputs

The towns of Hendersonville (2000 population: 10,580), Flat Rock (2000 population: 2,565), part of Laurel Park (2000 population: 2,017) and surrounding developed areas drain to Mud Creek, Devils Fork, Bat Fork, and many of their tributaries. Stormwater is directed to the creeks, carrying with it pollutants from parking lots, roads, roofs, other impervious surfaces, and lawns. Metals, hydrocarbons, road salt, and fecal contaminants are common in urban stormwater (Center for Watershed Protection, 2000). In addition to stormwater, city storm sewers often have unauthorized discharges, which are illegal under the Clean Water Act; these discharges include a wide range of sources, including connections of piped waste from businesses or residences, leaky sewage pipes, and misuse of storm drains.

Figure 2.13 Scraped bank along Bat Fork. Note collapsed sediment fence.

Roads. There is a large network of roads through the Mud Creek watershed, including Interstate 26, US 64, US 25, and US 176. These roads serve as conduits of stormwater, which carries metals and hydrocarbons built up on the road surfaces. Collisions involving trucks can be sources of pollutants. For example, in May 2000, 1,000 gallons of diesel fuel and 6,000 gallons of gasoline entered a tributary to Devils Fork when a fuel transport truck overturned on Interstate 26. To remediate impacts, the top soil layer of the area was removed; stream bank vegetation was removed in the process.

Sewers and septic systems. Sewer lines serve most of Hendersonville and some areas outside the city limits, including Laurel Park, Flat Rock, and developed areas to the northeast of Hendersonville. Sewer lines often parallel streams, including Mud Creek, Bat Fork, Wash Creek, Brittain Creek, King Creek, and Allen Branch. Spills of raw sewage can occur due to sewer line blockage, sewer overflow during storms, mechanical malfunction, incorrectly sized lines, or other inadequate infrastructure. From January 2000 through December 2001, there were 15 spills within the study area reported to DWQ by local governments (Table 2.6). These spills ranged in volume from 500 to 500,000 gallons of untreated sewage. Sewage spills may contain industrial and commercial waste as well as human sewage. Reported spills in the 2000-2001 period likely had little impact on monitoring data collected during this study. All spills occurred at least seven days before downstream water samples were collected for chemical/physical analysis. Biological monitoring was conducted at least three months after upstream spills except for the July 12, 2000 spill in Mud Creek; details are provided in Section 7.3. Due to the extent of sewer lines, potential sewage spill impacts are primarily limited to the lower Mud Creek and Bat Fork subwatersheds.

Septic systems are used to treat residential waste in much of the watershed outside of Hendersonville, Flat Rock, and Laurel Park, and there are still a few residences in these towns with septic systems, as well. Leaking septic systems can be a source of nutrients and fecal contamination for streams. Waste is occasionally straight-piped to streams, as well; straight pipes have been identified by DWQ project staff and the Henderson County Department of Public Health at various locations within the city and the county.

<u>Old city landfill</u>

Hendersonville operated a five acre landfill site in the 1940s and 1950s that is located near Jackson Park and Williams Street and is adjacent to Mud Creek. Its history is not well documented, but it is likely unlined and holds both incinerated and non-incinerated waste. The site is now covered with soil, and its past and present impacts to surface and groundwater are unknown.

Industrial stormwater

Nine industrial facilities have active stormwater permits in the study area, all operating under general permits (Table 2.7). Though the impervious areas associated with these facilities can be considerable, best management practices (BMPs) to control the quantity and timing of stormwater are not required in this watershed, and few facilities have implemented such practices. The general stormwater permits under which most of these facilities operate provide some measure of water quality protection, but do not require water quantity controls.

Table 2.6 Sewage Spills to Streams in the Mud Creek Watershed, January 2000 to December 2001

Date	Receiving Stream	Location	Volume (gallons)	Cause
1/10/00	Mud	Berkeley Rd.	10,000	Rain
1/29/00	Mud	Berkeley Rd.	500,000	Split Force Main
2/14/00	Mud	Berkeley Rd.	10,000	Rain
3/10/00	Unnamed tributary	Davis Mtn. Rd.	?	Broken pipe
3/20/00	Mud	White St./US 176	3,000	Rain
3/20/00	Mud	Berkeley Rd.	10,000	Rain
5/26/00	Clear	US 64	1,000	Valve
7/14/00	Mud	US 64	2,000	Electrical failure
7/12/00	Mud	US 64	1,100	Electrical failure
9/15/00	Bat Fork	US 176/Sheperd St.	2,000	Electrical failure
12/14/00	Brittain	Druid Hills	1,000	Grease
3/15/01	Mud	Duncan Hill Rd.	1,000	Grease
3/29/01	Mud	Berkeley Rd./Fresh Market	12,000	Rain
4/5/01	Brittain	Pardee Hospital	36,000	Debris
5/10/01	Allen Branch	Old Chimney Rock Rd.	500	Debris
Total Volume			**589,600**	

Groundwater contamination

There are a number of groundwater and underground storage tank incidents on file with the NC Department of Environment and Natural Resources within the Mud Creek watershed. Many of the sites have been closed. Of the active sites, only two have had documented impacts to surface waters, including the May 2000 fuel spill (see Urban Inputs) and the General Electric Superfund site.

Table 2.7 Facilities with General Stormwater Permits in the Mud Creek Watershed

Permit Number	Facility	Receiving Stream	Industry Type
NCG020176	Vulcan Materials-Hendersonville	Clear Creek	Mining
NCG050119	Printpack Incorporated	Hendersonville	Apparel, Printing, Leather, & Rubber
NCG050133	Poly Processing Incorporated	Lewis Creek	Apparel, Printing, Leather, & Rubber
NCG070156	Selee Corporation	King Creek	Stone, Clay, & Glass
NCG080182	United Parcel Service-Hendersonville	Devils Fork	Transit & Transportation
NCG140155	Southern Concrete Materials -Hendersonville	Mud Creek	Ready Mix
NCG160104	Apac Carolina Inc-Hendersonville	Clear Creek	Asphalt Paving Mixtures & Blocks
NCG160150	Tarheel Paving Co Asphalt Plant	Mud Creek	Asphalt Paving Mixtures & Blocks
NCG030500	GE Lighting Systems Inc	Bat Fork Creek	Low Voltage Lighting

The most significant groundwater contamination in the watershed is located at the US EPA Superfund site at General Electric (GE) Lighting Systems in the Bat Fork subwatershed (Figure 2.10). This site suffers from soil and groundwater contamination from polychlorinated biphenyls (PCBs), solvents, heavy metals, acids, and many different volatile organic compounds that were used and disposed of on-site throughout the plant's history. These contaminants were discovered in the soil and groundwater in the late 1980s, and beginning in 1997, GE has pumped contaminated groundwater from beneath the site, treating it with activated carbon.

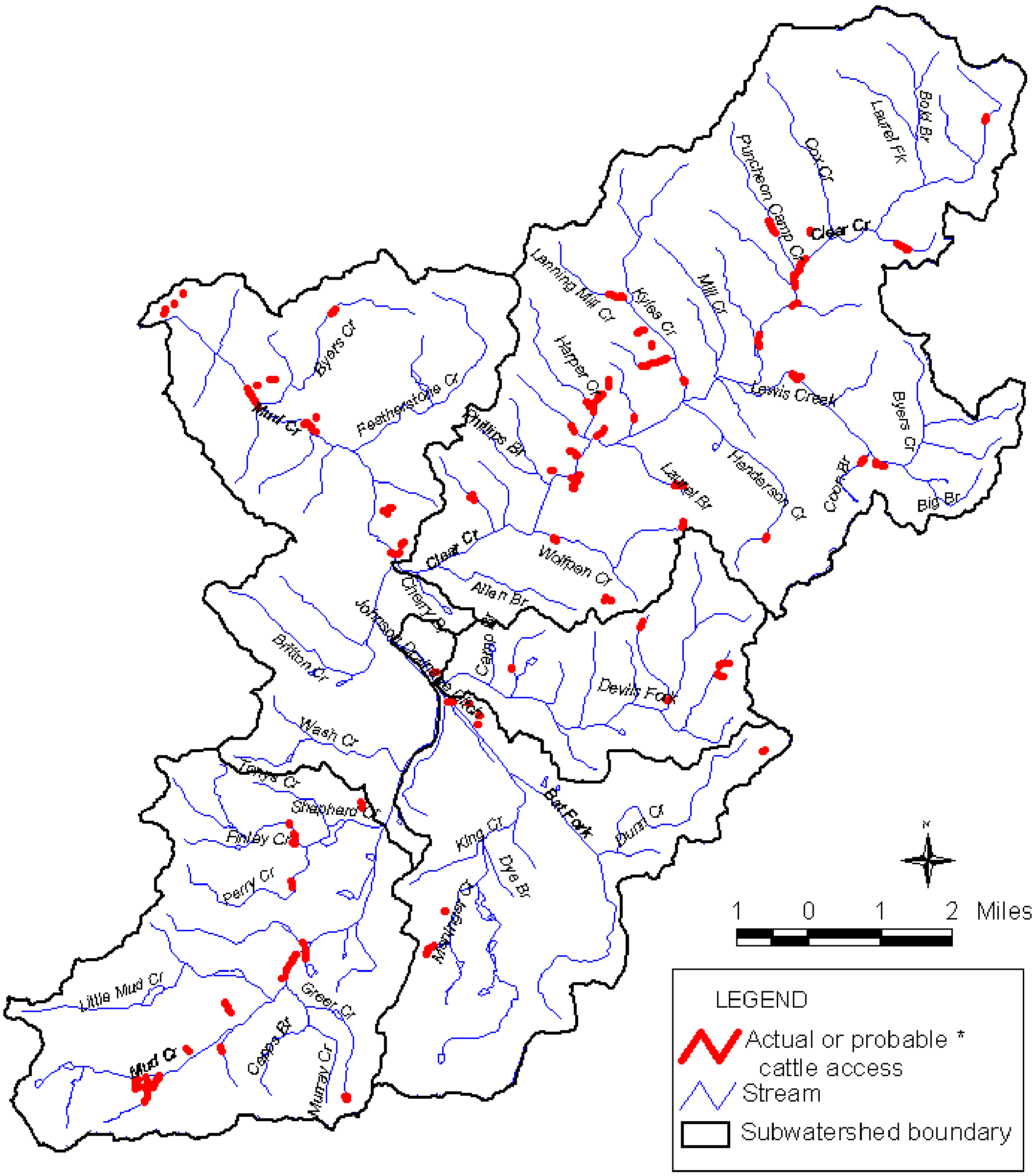
From l997 to 1999, all treated groundwater was discharged to Bat Fork. From 1999 to October 2000, 20-30% of the treated groundwater was discharged to Bat Fork, and the rest was sent to the Hendersonville WWTP. Since October 2000, all treated groundwater has been sent to the Hendersonville WWTP and the only discharge from GE to Bat Fork has come from stormwater runoff.

GE's Final Remedial Action System only addresses 50-60% of the groundwater plume due to (1) the presence of an endangered plant, the bunched arrowhead (*Saggitaria fasciculata*), in a wetland adjacent to Bat Fork on the GE property, and (2) local residents' concerns over well water usage on one side of the facility. In 1994, 2000, and 2001, six surface water samples were taken from Bat Fork adjacent to the GE facility and all six samples contained solvent contaminants at levels below surface water benchmarks (Table B.14, Appendix B). At this time, the final remedial action plan calls for sampling surface water in Bat Fork once a year in September. EPA's Record of Decision on this site can be accessed at http://cfpub.epa.gov/superrods/rodslist.cfm?msiteid=0402893.

<u>Agriculture</u>

Cattle. Cattle have direct access to a number of streams in the watershed (Figure 2.14). By grazing woody riparian vegetation and creating paths to a stream, cattle destabilize stream banks. They are responsible for severe stream degradation (Figures 2.15, 2.16) along a number of streams in the watershed (e.g., Mud Creek, Bat Fork, and Henderson Creek). Stream bank collapse contributes large amounts of sediment to a stream. Direct input of animal waste into streams and runoff from pasture and feeding areas are sources of nutrients and fecal

Figure 2.14. Cattle Access to Streams in the Mud Creek Watershed



*Probable stream access was defined as a stream segment that courses through an active pasture with no exclusion fence.
Source: TVA IPSI

contamination. According to the IPSI, cattle have actual or probable (stream in an active pasture but no exclusion fence observed) access to 11.2 miles of stream (2.5% of watershed stream miles).

Pesticides. Since row crop agriculture and apple orchards are such important land uses in the watershed (10% of total area), there is a potential for pesticides to impact water quality. Runoff from fields during storms, spills and runoff from pesticide mixing areas, back-siphoning and filter backwash from pesticide-irrigation systems, improper disposal of containers, and aerial drift are possible delivery mechanisms to surface waters.Tomatoes, peppers, and other vegetables are grown in floodplain areas with special drip irrigation systems. Water is pumped from an adjacent stream and pesticides are occasionally injected into the irrigation water. If the system is only used to deliver water and fertilizer, it is called a **fertigation** system; if it is used to deliver pesticides, it is called a **chemigation** system. In many such systems, no appropriate backflow prevention system exists, and substances injected into the system can be back-siphoned into the stream if the inflow pipe's backflow safety valve is non-functional or has been removed. A filter is backwashed after an irrigation cycle, and the backwash may be pumped directly into an adjacent stream.

A number of pesticides are frequently applied to tomatoes and peppers (Table B.51, Appendix B). The most common insecticides used are the organochlorine endosulfan and several pyrethroids—esfenvalerate, cyfluthrin, and lambda-cyhalothrin. Other insecticides that may be used include dimethoate and methamidophos (organophosphates), methomyl and oxamyl (carbamates), and imidacloprid (chloro-nicotinyl). Fungicides are applied every 7-10 days during the growing season and include chlorothalonil (an organochlorine), dithane, and azoxystrobin.

Figure 2.15 Cattle pasture in Henderson Creek.

Figure 2.16 Collapsed stream bank in upper Mud Creek.

Apple growers are also intensive users of pesticides (Table B.51, Appendix B). A number of past and on-going studies in the US and other countries (e.g., Heckman, 1981; Schulz, 2001) have documented pesticide impacts to streams from apple orchards. The bulk of pesticides are used from May through August. A large range of insecticides are used, including organophosphates chlorpyrifos, phosmet, and aziniphos-methyl; the organochlorine endosulfan; and pyrethroids esfenvalerate and permethrin. Captan, kresoxim-methyl, and trifloyxstrobin are some of the fungicides used. Paraquat, an herbicide, is also used in apple orchards. In recent years, there has been a decreased dependence on organochlorine and organophosphate insecticides due to their risk to humans and persistence in the environment, and decreased risk pesticides are more commonly used. However, the insecticides listed above have broad effectiveness for insects, and many are extremely toxic to aquatic insects. Some of these pesticides are also moderately to extremely toxic to fish.

Limited sampling by the DWQ Groundwater Section in September 2000 detected **organochlorine pesticides** no longer in use in drinking wells on the eastern edge of the Mud Creek watershed (Dana area). Five of eight wells were contaminated by organochlorine pesticides. Heptachlor epoxide and dieldrin were detected at levels greater than DWQ surface water and groundwater standards, and endrin was detected at levels greater than DWQ surface water standards.

Nutrients. Aside from pasture inputs, row crops can also be a source of nutrients. Drip irrigation systems, which are used to fertilize some row crops, can directly input nutrients via backflow siphoning and filter backwash. In addition, stormwater runoff from fields can be a nutrient source.

<u>Other non-point source inputs</u>
Activities near streams by landowners are also a source of non-point source pollution. The use of pesticides to control stream bank vegetation and in gardens can be problematic. Homes are often sited along streams, and runoff from roofs, driveways, and lawns are a source of nutrients, fecal contamination (from pets), and other pollutants. House construction near streams can be a source of contaminants, as well; substances such as those used for foundation treatments can end up in stormwater runoff, and equipment can be cleaned in adjacent creeks.

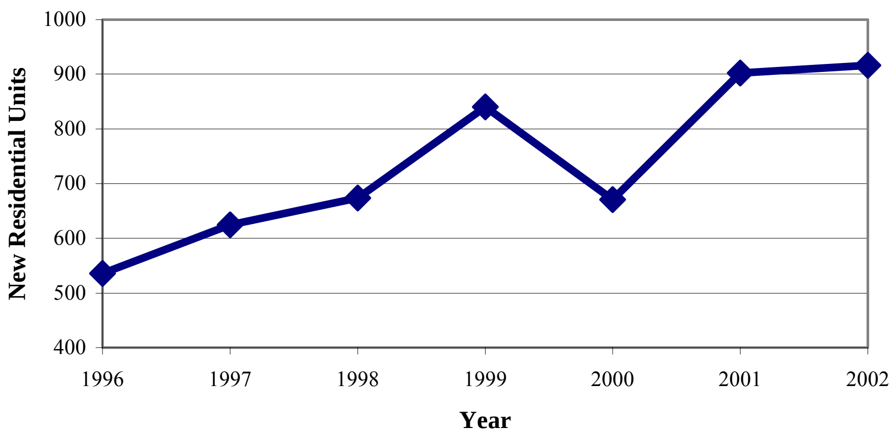
In addition to the agricultural and urban pesticide uses noted above, pesticides can also be used for mosquito control and to control inspect pests and unwanted vegetation along roadsides and power line rights-of-way. The Henderson County Health Department uses Biomist (permethrin) for mosquito control on an as-needed basis; in the past, malathion was used. The NC Department of Transportation (DOT) uses herbicides to control vegetation along portions of I-26 and US 64. Atrazine has historically been used for this purpose, but Roundup (glyphosate) is currently used. DOT does not generally use insecticides except for spot applications to control specific infestations. Duke Energy periodically sprays the herbicides Accord and Arsenal (glyphosate) to control woody vegetation along power transmission lines in the watershed.

Due to past channelization and removal of stream side vegetation, stream banks in this watershed are unstable and provide a significant source of sediment to the streams. Intensively manicured areas, including city parks, golf courses, and commercial areas are potential sources of pesticides and fertilizer.

2.6 Future Trends

Henderson County is growing at a rapid rate, with a 29% increase in population from 1990 to 2000 and a projected increase of 18% between 2000 and 2010 (US Census Bureau, Henderson County Planning Department). A corresponding shift in land use from agricultural and forest to residential and commercial uses is expected. Since 1996, the number of building permits issued for new residential units in Henderson County has generally increased (Figure 2.17). Much of this development will be along the I-26, US 25, US 64, and US 176 corridors.

Figure 2.17. Residential Units in Henderson County 1996-2002



2.7 Regulatory Issues and Local Water Quality Activities

2.7.1 Applicable Ordinances

A set of state and local regulatory programs impact development and water quality protection in the Mud Creek watershed:

Henderson County Ordinances
The Subdivision Ordinance and the Manufactured Home Park Ordinance both require that stormwater drainage facilities be constructed to minimize erosion and sedimentation, minimize flooding, and avoid excessive discharge. However, specifications for post-development stormwater discharge volume and rate are not addressed.

Hendersonville Ordinances
- *Floodway and floodway fringe development.* Development is limited in the floodway (land adjacent to a stream that is reserved from building in order to avoid an increase of more than 1 ft in flood elevation during the 100-yr flood) and floodway fringe in order to minimize public and private losses due to flood conditions. It provides guidance to control the alteration of natural floodplains, stream channels, and natural protective barriers involved in the accumulation of flood waters, including filling, grading, dredging, or other development which may increase erosion or flood damage. Redevelopment in the floodway and fringe must include BMPs to reduce post-redevelopment stormwater rate if feasible.
- *Stormwater management.* Any development that includes impervious surfaces greater or equal to 0.5 acres must submit a stormwater management plan with stormwater controls. Post-development runoff rate must not exceed the pre-development rate.

- *Natural Resources Protection Ordinance.* This contains a stream buffer protection standard that requires protection of a 50-foot buffer on both sides of blue line streams identified on the current USGS quadrangle maps. Existing uses of the buffer zone are allowed. The 50-foot buffer is divided into two zones—a 30-foot area of undisturbed vegetation followed by a 20-foot belt of either managed or unmanaged vegetation.

Flat Rock Ordinances

- *Subdivision buffer requirement.* This requires protection of a 50-foot set back on perennial streams, lakes, and wetlands that appear on USGS topographic maps; the setback is divided into two areas—a 25-foot zone of natural vegetation followed by a 25-foot belt of either managed or natural vegetation. Perennial streams that are not on USGS topographic maps require a 10-foot buffer of natural vegetation.
- *Floodplain ordinance.* No structures (with some exceptions) or fill are allowed in the 100-year floodplain.
- *Stormwater management.* Both subdivisions and other types of commercial and residential developments are required to construct stormwater drainage facilities to prevent downstream erosion/sedimentation and follow existing natural drainage. Where feasible, stormwater discharge points must discharge through vegetated areas. In addition, commercial and residential developments (excluding subdivisions) are required to have stormwater controls to insure that post-development stormwater runoff rates do not exceed pre-development rates.

State stormwater regulations

The Mud Creek watershed is not currently subject to any state stormwater regulations, but this will change in the near future. EPA has developed a Phase II stormwater program, mandating that small communities not previously subject to federal stormwater requirements apply for permit coverage. Under the new Phase II stormwater program, Hendersonville, Flat Rock, and Laurel Park are required to develop and implement a comprehensive stormwater management program. This program must include six minimum measures: 1) public education and outreach on stormwater impacts; 2) public involvement/participation; 3) unauthorized discharge detection and elimination; 4) construction site stormwater runoff control; 5) post-construction stormwater management for new development and redevelopment; and 6) pollution prevention/good housekeeping for municipal operations. According to NC temporary rules, Hendersonville, Flat Rock, and Laurel Park are required to apply for stormwater permit coverage by May 2004.

NC temporary rules require Henderson County to address measures (4) and (6), complying with the US EPA deadline of March 2003 for a permit application. If the County is exempted from this program due to a lack of storm sewer conveyance systems outside already designated municipalities, it does not have to comply with the Phase II stormwater regulations.

2.7.2 Local Water Quality Initiatives

Volunteer Water Information Network. Volunteer Water Information Network (VWIN) is a water quality monitoring program run by citizens and the Environmental Quality Institute (EQI) at the University of North Carolina at Asheville. Volunteers collect monthly samples at nine locations in the Mud Creek watershed. Samples are sent to EQI for analysis of twelve parameters, including nutrients, metals, and turbidity. The Environmental and Conservation Organization, based in Hendersonville, administers the monitoring program.

NC Wetlands Restoration Program planning efforts

In 2001, the NC Wetlands Restoration Program (NCWRP), an agency in the Department of Environment and Natural Resources, initiated a nonregulatory local watershed planning effort in the Mud Creek watershed. The local watershed plan (LWP) is a comprehensive planning process in which NCWRP is working with local stakeholders to:

- inventory water quality, flooding and habitat problems in the watershed;
- identify solutions, including stream and wetland restoration opportunities, and appropriate best management practices; and
- implement strategies for restoring and protecting streams and wildlife.

DWQ’s assessment of the Mud Creek watershed and the NCWRP’s LWP are complementary efforts, but the two initiatives have distinct emphases. The current DWQ study is primarily a technical assessment of the causes and sources of stream impairment. The NCWRP effort encompasses a wider range of objectives and incorporates extensive stakeholder involvement, including the identification of specific sub-watersheds where the implementation of restoration projects and/or stormwater BMPs could achieve the greatest benefit. Results of the DWQ assessment are being used in the NCWRP planning process. The LWP is scheduled to be completed by the summer of 2003, with specific project implementation efforts to follow over the next several years.

Mud Creek Watershed Restoration Council

The Mud Creek Watershed Restoration Council is a group of Henderson County citizens and government representatives that aims to educate the public about water quality in the watershed, develop a management strategy to improve and protect streams in the watershed, and effect restoration activities. It is working closely with DWQ and NCWRP staff to develop its watershed management strategy, which incorporates results from DWQ’s assessment, TVA’s IPSI, and VWIN data.

Section 3
Methods Used for Data Collection and Analysis

This study used a wide range of data to evaluate the most likely causes of biological impairment in the Mud Creek watershed. Project staff monitored the biological community, water chemistry and toxicity, sediment chemistry and toxicity, and in-stream habitat quality. Other information, such as the land use/cover and buffer information described in Section 2, was also used. A strength of evidence approach was used to weigh the evidence for or against each stressor considered in order to determine which are the most likely causes of impairment.

In Sections 4 through 7, data are presented and analyzed and conclusions about the nature and causes of impairment are developed for each subwatershed. General background information needed to understand data collection and analysis methods are documented in this section.

3.1 Land Use/Cover Data

At the request of the Mud Creek Watershed Restoration Council and the NC Wetlands Restoration Program, TVA developed an Integrated Pollution Source Identification (IPSI) for the Mud Creek watershed. The IPSI is a geographic database and pollutant loading model based on interpretation of low-altitude color infrared aerial photographs taken in March 2001 (TVA, 2001).

The geographic database consists of information on stream, riparian area, and watershed features. Stream information includes extent of channelization, bank stability, and livestock access. Bank stability is characterized as eroding or not eroding, but since aerial photographs were the only data source used, only larger eroding sections of stream were identified with this method. Riparian area vegetation was characterized by vegetation width, type (woody or herbaceous), and condition. Watershed features include land use/cover, impervious cover, livestock operations, and roads. Impervious cover was determined by analyzing the percent impervious cover for each land polygon distinguished in the land use/cover dataset. The present DWQ study used these datasets to characterize watershed and riparian area conditions, relating these data to biological, chemical, and habitat data collected in the field.

The pollutant loading model estimates pollutant (sediment, nutrients) loadings from land use/cover types. Pollutant loadings were estimated using a number of different equations, including the universal soil loss equation, EPA's urban pollutant load equations (USEPA, 1990), and delivery ratio equations incorporating the best professional judgment of a local Natural Resources Conservation Service agent. DWQ's assessment of the Mud Creek watershed generally did not use results from this pollutant loading model.

3.2 Biological Conditions and Stream Habitat

Bioassessment involves the collection of stream organisms and the evaluation of community diversity and composition to assess water quality and ecological conditions in a stream.

Evaluation of habitat conditions at sampling locations is an important component of bioassessment.

DWQ's Biological Assessment Unit has a dataset from the Mud Creek watershed that spans several decades. In order to study the stream communities of apple orchard areas, benthic macroinvertebrates (or benthos) were sampled in 1977-78 in the Clear Creek subwatershed. Benthic macroinvertebrate communities at sites below apple orchards were severely impacted. Benthic macroinvertebrates have been monitored in Bat Fork and Mud Creek since the 1980s. Fish communities of Mud Creek and Bat Fork were monitored in 1997 by DWQ; Tennessee Valley Authority monitored fish communities of Mud Creek and Clear Creek that same year. Benthic and fish communities of these streams were also indicative of water quality and habitat problems.

Additional benthic and fish community sampling was conducted during the present study to serve several purposes:

- To account for any changes in biological condition of these creeks since they were last monitored.
- To obtain more specific information on the actual spatial extent of impairment than is possible with existing data.
- To better understand which portions of the watershed may be contributing to biological impairment and which areas are in good ecological condition.
- To collect additional information to support a biologically-driven identification of likely stressors.

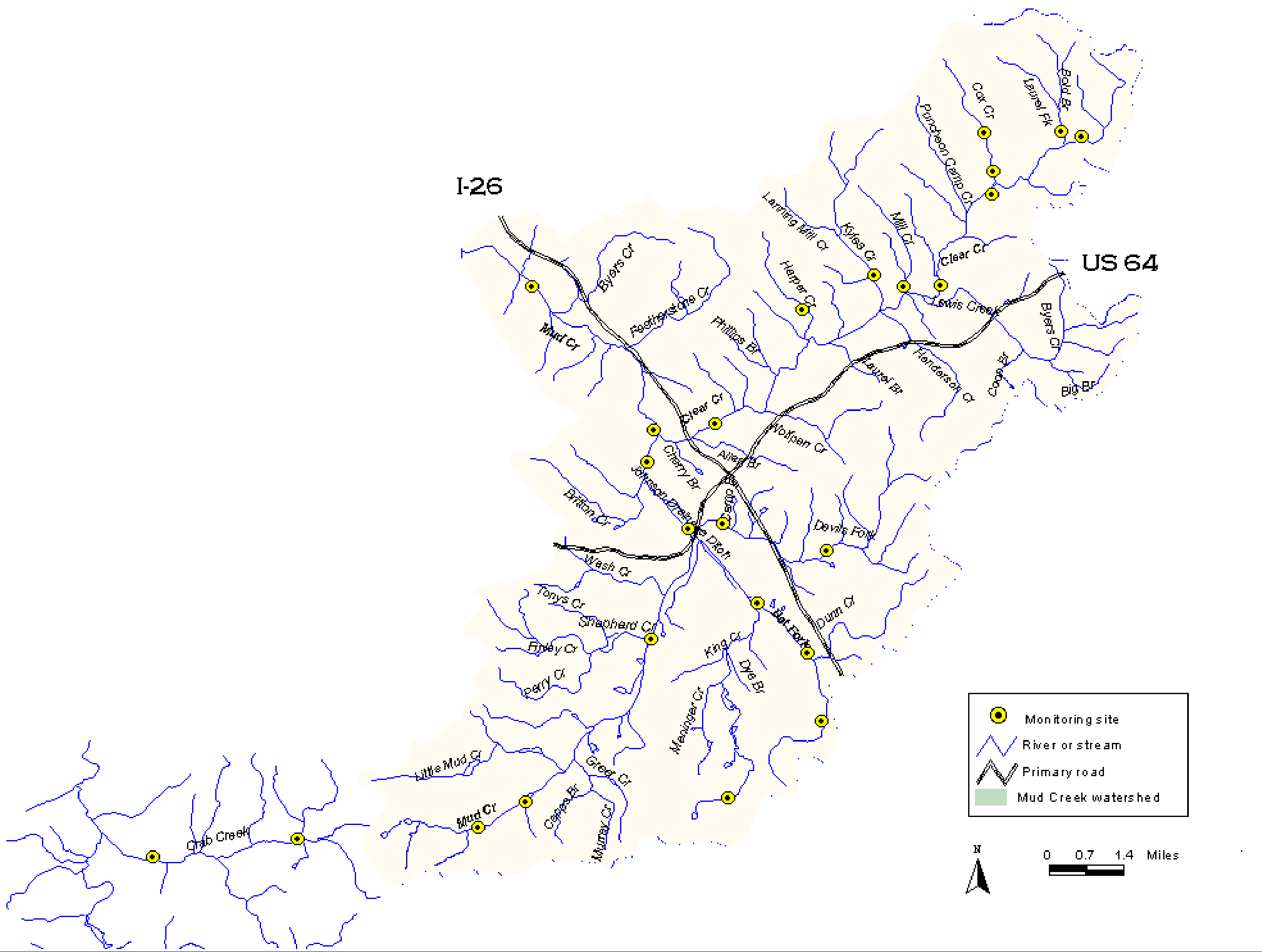
3.2.1 Approach to Biological and Habitat Assessment

Benthic macroinvertebrate community samples were collected at 23 sites in the Mud Creek watershed between July 2000 and October 2001 (Figure 3.1). In order to compare study streams to relatively unimpacted streams, two reference sites were chosen in the adjacent Crab Creek watershed. All benthic sampling was performed between July 2000 and October 2001. Individual sites are described in subsequent sections of this report.

3.2.2 Benthic Community Sampling and Rating Methods

Macroinvertebrate sampling followed procedures outlined in DWQ's standard operating procedures (NCDWQ, 2001a). Standard qualitative methods were used for streams with a width of at least four meters. This method includes ten composite samples: two kicks, three sweeps, one leafpack, one sand sample, two rock/log washes, and a visual collection. The Qual 4 sampling procedure was used for sites less than four meters wide in 2000. This procedure involves four composite samples: one kick, one sweep, one leafpack sample, and visual collections. The Qual 5 method was used for sites less than four meters wide in 2001, and includes the four composite samples collected with a Qual 4 plus a rock/log wash, which was added to obtain a better sample of the midge community. Organisms were identified to genus and/or species. Sampled reaches were approximately 100 meters in length. Details of the methods used at each sampling station are included in Appendix A.

Figure 3.1. Benthic Monitoring Sites in the Mud Creek Watershed Study



Two primary indicators or metrics are derived from macroinvertebrate community data: 1) the diversity of a more sensitive subset of the invertebrate fauna is evaluated using EPT taxa richness counts; and 2) the pollution tolerance of those organisms present is evaluated using a biotic index (BI). "EPT" is an abbreviation for Ephemeroptera + Plecoptera + Trichoptera (mayflies, stoneflies and caddisflies), insect groups that are generally intolerant of many kinds of pollution. *Generally, the higher the EPT number, the healthier the benthic community.* A low BI indicates a community dominated by taxa that are relatively sensitive to pollution and other disturbances (*intolerant*). A high BI indicates greater dominance by organisms that are pollution and disturbance insensitive (*tolerant*). *Thus, the lower the BI number, the healthier the benthic community.* Biotic index numbers were combined with EPT taxa richness ratings to produce a final bioclassification (Good, Fair, Poor, etc).

Streams that are at least four meters wide are formally rated with standard qualitative criteria. Rating methods are currently under development for streams less than four meters wide; however, these smaller streams may be rated if certain conditions are met. If an unimpacted, high quality stream is sampled with Qual 4 procedures, a size correction factor is applied and a rating given. Generally, larger streams host more invertebrate taxa; thus if rating methods for streams at least four meters wide are used for smaller streams, the smaller streams may be "under-rated". If a stream is sampled using Qual 4 procedures but is impacted by human disturbance, it is rated as Not Impaired (NI) if it meets the criteria for a Good-Fair or higher rating using the standard qualitative criteria. If this stream would not be Good-Fair or higher using standard qualitative criteria, it is listed as Not Rated (NR). All streams sampled with Qual 5 methods are considered NR because Qual 5 rating methods are still being developed.

Final bioclassifications are used to determine if a stream is impaired. Streams with bioclassifications of Excellent, Good, and Good-Fair are all considered to be supporting their designated uses. Those with Fair and Poor ratings are considered impaired and are typically added to the State's 303(d) list.

3.2.3 Fish Community Sampling and Rating Methods

Between 2001 and 2002, fish were sampled using NC Index of Biotic Integrity (NCIBI) protocols (NCDWQ, 2001b) at five sites in the Mud Creek watershed. At each site, the fish within a 600-ft reach were collected using two backpack electrofishing units with each unit accompanied by 1 or 2 persons dip netting. A seine was also used to sample fish inhabiting the riffle areas. After collection, all readily identifiable fish were examined for sores, lesions, fin damage, and skeletal anomalies, measured (total length to the nearest 1 mm), and then released. Once the first 50 specimens of each species were measured, the remaining fish of each particular species were just counted and then also released. Those fish that were not readily identifiable in the field were preserved in 10% formalin and returned to the laboratory for identification, examination, and total length measurement. Young-of-year fish were not included in the analyses.

NCIBI scores are determined by considering a number of individual metric scores, including number of species, number of fish, number of minnow species, number of darter species, number of rockbass, smallmouth bass, and trout species, number of intolerant species, percentage of insectivores, percentage of omnivores and herbivores, percentage of tolerants, and percentage of species with multiple age groups. NCIBI scores are translated into bioclassifications as for benthic macroinvertebrate communities (Excellent, Good, Good-Fair, Fair, and Poor). As with benthic data, streams with bioclassifications of Excellent, Good, and Good-Fair are all considered to be supporting their designated uses. Those with Fair and Poor ratings are considered impaired and are typically added to the State's 303(d) list.

Because the fish community dataset was limited to only five monitoring sites and some data were collected outside the study's data collection period (2000-2001), fish community data were used to supplement benthic results. *Identification of causes and sources of impairment was largely based on benthic data.*

3.2.4 Habitat Assessment Methods

At the time benthic and fish community sampling was carried out, stream habitat and riparian area conditions were evaluated for each reach using DWQ's standard habitat assessment protocol for mountain streams (NCDWQ, 2001a). This protocol rates the aquatic habitat of the sampled reach by adding the scores of a suite of local (reach scale) habitat factors relevant to fish and/or macroinvertebrates. Total scores range from one (worst) to 100 (best). Individual factors include (maximum factor score in parenthesis):

- channel modification (5);
- in-stream habitat variety and area available for colonization (20);
- bottom substrate type and embeddedness (15);
- pool variety and frequency (10);
- riffle frequency and size (16);
- bank stability and vegetation (14);
- light penetration/canopy coverage (10); and
- riparian zone width and integrity (10).

3.3 Chemical and Toxicological Conditions

Water quality assessment provides information to evaluate whether chemical and physical conditions negatively affect benthic communities. DWQ has an ambient monitoring station on lower Mud Creek, where it has collected samples that are analyzed for standard parameters, including nutrients, metals, turbidity, and fecal coliform bacteria, once a month since 1991. The Volunteer Water Information Network (VWIN) has nine sites throughout the watershed, where it collects monthly samples that are analyzed for many of the same parameters (Maas et al., 2002). Most of VWIN's sites have been sampled since 1992. In the present study, ambient conditions were assessed in the field and surface water samples were collected for laboratory analysis to evaluate water quality. Two broad purposes of this monitoring were:

1. To characterize water quality conditions in the watershed.
2. To collect a range of chemical, physical and toxicity data to help evaluate the specific causes of impairment and to help identify the sources.

The approach to chemical and toxicological monitoring for this study is summarized below. For additional details, refer to Appendix B.

3.3.1 Approach to Chemical and Toxicological Sampling

General Water Quality Characterization. Five stations located at the downstream ends of subwatersheds were sampled on a near monthly basis to characterize water quality conditions. Since these sites tended to integrate most subwatershed impacts, they were named integrator sites. A standard set of parameters similar to those evaluated at DWQ ambient stations was used (Appendix Table B.1). Samples were collected during both baseflow and stormflow periods. Baseflow periods were defined as those in which no measurable rain fell in the watershed during the 48-hour period preceding sampling. Storm samples were collected on the rising stage of the hydrograph. Fecal coliform samples were collected only under baseflow conditions.

Stressor and Source Evaluation. Samples were collected at a number of locations in order to identify major chemical/physical stressors to which aquatic biota are exposed and assess major sources. Station locations were linked closely to areas of known biological impairment (benthic macroinvertebrate sampling stations) and to specific watershed activities believed to represent potential sources of impairment.

In addition to standard parameter sampling, the water samples of some streams were analyzed for a broad set of pesticides by the NCSU Department of Environmental and Molecular Toxicology. Acid herbicides, chlorinated pesticides, nitrogen pesticides, organophosphate pesticides, were also analyzed for some samples by the DWQ laboratory. Many current-use pesticides could not be analyzed with these methods (Table B.51, Appendix B). At some sites, samples were also analyzed for non-pesticide organic contaminants, including semi-volatile organics, methyl tertiary-butyl ether (MTBE), phenols, polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbons for diesel and gasoline, methylene blue active substances (MBAS, an indicator of anionic surfactants), and volatile organic pollutants.

Suspended sediment was sampled during storm events with stationary multi-stage samplers at eleven watershed locations to characterize sources of sediment in the watershed.

Semi-permeable membrane devices and stream sediments were used to measure long-term stream exposure to pollutants. Semi-permeable membrane devices (SPMDs), passive artificial samplers that accumulate hydrophobic organic pollutants, were used during multiple day periods. The SPMDs were analyzed for PAHs, polychlorinated biphenyls (PCBs), organochlorine pesticides, and selected current use pesticides.

Hydrolab® data sondes, multiparameter probes with a data logging capability, were used to measure dissolved oxygen, temperature, specific conductance, and pH levels in-stream during multi-day periods.

Ambient acute and chronic toxicity tests (bioassays) were conducted on water samples. Laboratory bioassays provide a method of assessing the presence of toxicity from either single or multiple pollutants and can be useful for assessing the cumulative effect of multiple chemical stressors. The North Carolina *Ceriodaphnia* Chronic Effluent Toxicity Procedure (NCDWQ, 1998) was used for chronic toxicity determination. Acute toxicity was determined using protocols defined by USEPA using *Ceriodaphnia dubia* with a 48-hour exposure (USEPA, 1993).

Stream bed sediments were collected in August 2001 and analyzed for pesticides, metals, and a suite of organic pollutants, including PAHs, PCBs, and other semi-volatile compounds. Chronic toxicity tests were conducted on these sediments to evaluate potential toxic impacts. Forty-two day tests were performed with the test organism *Hyallela azteca*, using methods described in ASTM (2000) and USEPA (2000b).

Field measurements (pH, dissolved oxygen, specific conductance and temperature) were taken on multiple occasions at various locations throughout the watershed to further characterize water quality conditions and to investigate potential stressor source areas.

<u>Water and sediment benchmarks</u>. To help evaluate whether a significant likelihood existed that observed concentrations may have a negative impact on aquatic life, measured concentrations were compared to EPA's National Ambient Water Quality Criteria (NAWQC) for freshwater (USEPA, 1999) and Tier II benchmarks (USEPA, 1995). Metals benchmarks were adjusted for hardness where appropriate (USEPA, 1999). For chromium, the NAWQC for Cr VI was used. The use of NAWQC and other benchmarks is discussed in more detail in Appendix B. Since NAWQC criteria are for dissolved metals and samples of the Mud Creek watershed were analyzed for total metals, these criteria are conservative.

Sediment data were compared to a set of sediment benchmarks used by the DWQ Aquatic Toxicology Unit (Table B.2, Appendix B). Benchmarks were grouped into conservative and non-conservative ranges in the manner of MacDonald et al. (2000). Conservative ranges are sets of threshold values, below which there is low probability of toxicity. Region 4 USEPA values are included in the set of conservative values, but they are also presented by themselves because the DWQ Aquatic Toxicology Unit uses these as initial screening benchmarks. Non-conservative ranges are sets of probable values, above which there is a high probability of toxicity. If a measured value falls between the low value of the conservative range and the high value of the non-conservative range, it is possible but not probable that it is toxic; the higher the concentration is, the greater the probability of toxicity.

Benchmarks were used for initial screening of potential impacts. Final evaluation of the likely potential for metals, and other analytes, to negatively impact aquatic biota, considered all lines of evidence available, including toxicity bioassays and benthic macroinvertebrate data, in addition to data on analyte concentrations.

<u>Volunteer Water Information Network (VWIN) data</u>. VWIN data on water samples collected from 2000 and 2001 were used to supplement the chemical and physical water quality data collected during this study. These data are not directly comparable to data collected by DWQ during this study due to differences in analytical methodology, detection limits, statistical issues, and lack of flow distinction (see Appendix B for details).

3.4 Stream Channel and Riparian Conditions

The characterization of stream habitat and riparian area condition at benthic macroinvertebrate sampling sites, described earlier, provides information essential to the assessment of conditions in the Mud Creek watershed. However, a perspective limited to a small number of locations in a watershed may not provide an accurate picture of overall channel conditions, nor result in the identification of pollutant sources and specific problem areas. This study therefore undertook a broader characterization of stream condition by examining large sections of the channel network. This characterization is critical to an evaluation of the contribution of local and regional habitat conditions to stream impairment and to the identification of source areas and activities.

During the course of this study, project staff walked or kayaked the entire channel of Mud Creek from Walnut Cove Rd. to North Rugby Rd., most of the channel of Bat Fork from its headwaters to its confluence with Mud Creek, and small sections of other streams in the Mud Creek watershed.

Project staff walked the identified sections of channel while carrying out the following tasks:

- Observing overall channel stability, noting specific areas of sediment deposition, severe bank erosion, evidence of channelization and similar attributes.
- Observing overall riparian area condition and the nature of surrounding land use.
- Identifying wastewater discharge pipes, stormwater outfalls, other piped inputs or withdrawals, and tributary inflows.
- Observing visual water quality conditions (odors, surface films, etc).
- Noting specific areas where pollutants are or may be entering the stream (livestock access areas, dump sites, land clearing adjacent to the stream, etc).
- Identifying specific areas that may be candidates for channel restoration or best management practices.
- Providing digital photo documentation of key features.

3.5 Analyzing Causes of Impairment

This study summarizes and evaluates the available information related to each candidate cause of impairment in order to determine whether that information provides evidence that that particular stressor plays a substantial role in causing observed biological impacts. A strength of evidence approach was used to weigh the evidence for or against each stressor in order to draw conclusions regarding which are the most likely causes of impairment. Causes of impairment may be single or multiple. All stressors present may not be significant contributors to impairment. (See the sidebar "Identifying Causes of Impairment", presented in Section 1, for additional discussion.)

3.5.1 A Framework for Causal Evaluation—the Strength of Evidence Approach

A ‘strength of evidence’ or ‘lines of evidence’ approach involves the logical evaluation of all available types (lines) of evidence to assess the strengths and weaknesses of that evidence in order to determine which of the options being assessed has the highest degree of support (USEPA, 1998; USEPA, 2000b). The term ‘weight of evidence’ is sometimes used to describe this approach (Burton and Pitt, 2001), though this terminology has gone out of favor among many in the field because it can be interpreted as requiring a mathematical weighting of evidence.

This report considers all lines of evidence developed during the course of the project using a logical process that incorporates existing scientific knowledge and best professional judgment to consider the strengths and limitations of each source of information. Lines of evidence considered include benthic macroinvertebrate community data, habitat and riparian area assessment, chemistry and toxicity data, and information on watershed history, current watershed activities and land uses and pollutant sources. The ecoepidemiological approach described by Fox (1991) and USEPA (2000b) provides a useful set of concepts to help structure the review of evidence. The endpoint of this process is a decision regarding the most probable causes of the observed biological impairment and identification of those stressors that appear to be most important. Stressors are categorized as follows:

- **Primary cause of impairment.** A stressor having an impact sufficient to cause biological impairment. If multiple stressors are individually capable of causing impairment, the primary cause is the one that is most critical or limiting. Impairment is likely to continue if the stressor is not addressed. All streams will not have a primary cause of impairment.
- **Secondary cause of impairment.** A stressor that is having an impact sufficient to cause biological impairment but that is not the most critical or limiting cause. Impairment is likely to continue if the stressor is not addressed.
- **Cumulative cause of impairment.** A stressor that is not sufficient to cause impairment acting singly, but that is one of several stressors that cumulatively cause impairment. A primary cause of impairment may not exist. Impairment is likely to continue if the various cumulative stressors are not addressed. Impairment may potentially be addressed by mitigating some but not all of the cumulative stressors. Since this cannot be determined in advance, addressing each of the stressors is recommended initially. The actual extent to which each cause should be mitigated must be determined in the course of an adaptive management process (see Section 8.3).
- **Contributing stressor.** A stressor that contributes to biological degradation and may exacerbate impairment but is not itself a cause of impairment. Mitigating contributing stressors is not necessary to address impairment, but should result in further improvements in aquatic communities if accomplished in conjunction with addressing causes of impairment.
- **Potential cause or contributor.** A stressor that has been documented to be present or is likely to be present, but for which existing information is inadequate to characterize its potential contribution to impairment.
- **Unlikely cause or contributor.** A stressor that is likely not present at a level sufficient to make a notable contribution to impairment. Such stressors are likely to impact stream biota in some fashion but are not important enough to be considered causes of or contributors to impairment.

Stressors are categorized in the above fashion to prioritize benthic community impacts. Due to the limited fish community dataset, stressors impacting the fish community are discussed in each section but not labeled with the above terms.

Section 4
Results and Conclusions: Upper Mud Creek Subwatershed

Mud Creek is considered impaired for its entire length in the upper Mud Creek subwatershed, which is defined as the area upstream of Erkwood Drive. Prior to the present study, DWQ's Biological Assessment Unit had monitored benthic macroinvertebrates at one site in the subwatershed—Mud Creek at Berea Church Rd.—and a severely degraded community was found. This site is in the upper rural part of the subwatershed and was impacted by waste from dairy farm lagoons. Discharges from poorly managed waste lagoons located next to Mud Creek were noted in the 1990s. The threat of waste inputs to Mud Creek from these lagoons greatly decreased once their use was discontinued in late 1998, and they were officially closed in the spring of 2001.

The Volunteer Water Information Network (VWIN) samples at two sites on the Mud Creek mainstem in the subwatershed. Data collected before the onset of the present study indicated high nutrient levels below the dairy farm.

4.1 Key Stressors Evaluated in the Upper Mud Creek Subwatershed

Plausible causes of biological impairment in the Mud Creek watershed were identified using both bioassessment and watershed-driven approaches (Figure 1.2). Biological community data, habitat information, and land uses and activities were considered to flag stressors for further investigation. Based on preliminary review, the following stressors were evaluated as the most plausible candidate causes of impairment in upper Mud Creek for further investigation:

1. Habitat degradation due to sedimentation. Habitat degradation due to sedimentation manifests itself in the loss of pools, burial of riffles, and high levels of substrate instability. Excess sedimentation was historically listed as a problem parameter for Mud Creek on the 303(d) list.

2. Pesticides. Pesticides used on row crops (including tomatoes and peppers) in the floodplain, on residential gardens and lawns, and on golf courses could impact benthic communities.

4.2 Monitoring Locations

Monitoring site locations as listed below were chosen in order to characterize stream integrity, identify stressors, and pinpoint sources of these stressors. Benthic invertebrate communities, water chemistry, and sediment chemistry were monitored in this subwatershed primarily during the period of 2000-2001 (Figure 4.1, Table 4.1). VWIN chemical data were also used in this analysis.

Figure 4.1 Monitoring Sites in the Upper Mud Creek Subwatershed

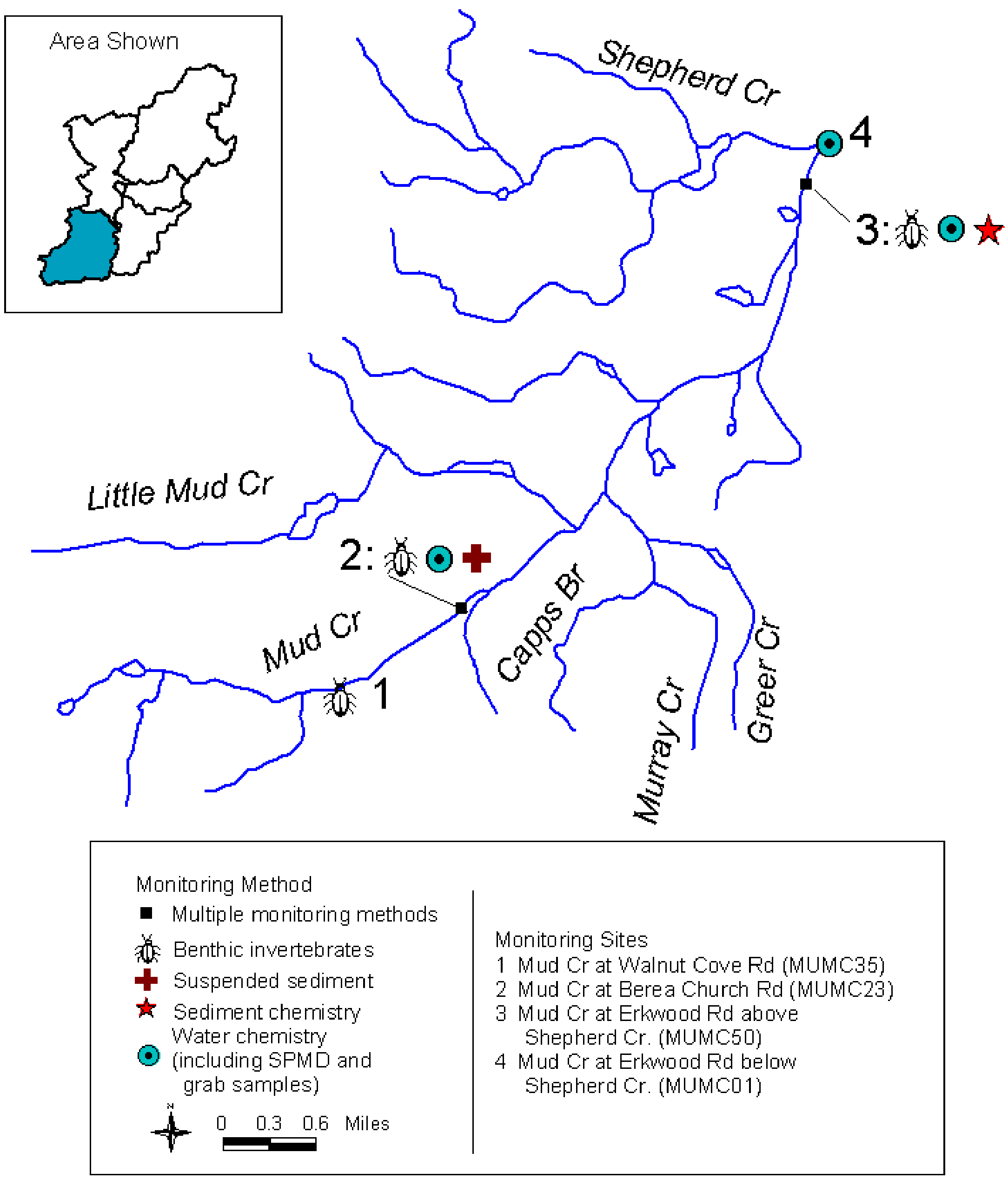


Table 4.1 Summary of Monitoring Approaches Used at Primary Sampling Sites, Upper Mud Creek Subwatershed

Station Code	Location	Benthos	DWQ Water Quality[1]	VWIN Water Quality[1]	SPMD	Suspended Sediment	Sediment Quality
MUMC35	Mud Cr. at Walnut Cove Rd.	✓					
MUMC23	Mud Cr. at Berea Church Rd.	✓		✓		✓	
MUMC50	Mud Cr. at Erkwood Rd. above Shepherd Cr.	✓	✓		✓		✓
MUMC01	Mud Cr. at Erkwood Rd. below Shepherd Cr.		✓+	✓			

[1] Grab samples and/or repeated field measurements.
\+ Integrator station.

<u>Mud Creek Mainstem (Upstream to Downstream)</u>

- *Mud Creek at Walnut Cove Rd. (SR 1125)* (MUMC35). This is the furthest upstream benthic monitoring site, upstream of a set of tomato fields near Berea Church Rd.
- *Mud Creek at Berea Church Rd. (SR 1126)* (MUMC23). This sampling location is downstream of severe stream bank erosion and a set of tomato fields. Benthic macroinvertebrates and suspended sediment were monitored here. It is also a VWIN chemistry site.
- *Mud Creek at Erkwood Rd. above Shepherd Creek (SR1164)* (MUMC50). This site integrates much of the agricultural impacts of upper Mud Creek and is above urban impacts. It was sampled for benthic macroinvertebrates and stormflow and sediment chemistry. Chemical sampling focused on agricultural and golf community pesticides, using grab samples and semi-permeable membrane devices (SPMDs). Sediments were also collected and analyzed for toxicity and chemistry.
- *Mud Creek at Erkwood Rd. below Shepherd Creek (SR 1164)* (MUMC01). This site was a WARP integrator location and also a VWIN site.

4.3 Characterization of the Biological Community and Stream Habitat

4.3.1 Description

Selected habitat and biological characteristics for each site sampled during the study are shown in Table 4.2. Some streams were too small to be given a formal rating (bioclassification). See Section 3.2.2 and Appendix A for additional details. A narrative summary of conditions at each site follows.

Table 4.2 Selected Benthic Community and Habitat Characteristics at Study Sites in the Upper Mud Creek Subwatershed[1]

Site	Date	Substrate % sand and silt[2]	In-stream Structure Score (of 20)[3]	Embedded-ness Score (of 15)[4]	Habitat Score Total (of 100)[5]	EPT Richness[6]	EPT Biotic Index[6]	Biotic Index[6]	Bioclassification[6]
Mud Creek at Walnut Cove Rd.	10/25/00	60	14	4	58	23	3.82	4.65	Not impaired—at least Good-Fair
	10/03/01	65	16	6	61	22	4.08	4.82	Not impaired—at least Good-Fair
Mud Creek at Berea Church Rd.	9/8/97	80		3	42	2	6.99		Not Rated
	7/11/00	90	9	3	52	16	5.30	6.21	Not Rated*
	10/25/00	80	7	3	30	5	4.60	7.07	Not Rated*
	10/03/01	-	12	2	38	15	5.11	5.96	Not Rated*
Mud Creek at Erkwood Rd. above Shepherd Cr.	10/04/01	80	11	3	44	11	5.71	6.69	Fair

1 For samples pre-2000, biotic index and in-stream structure scores are not available due to differences in sample methods.
2 Based on visual estimate of substrate size distribution.
3 Visual quantification of the of in-stream structures present, including leafpacks and sticks, large wood, rocks, macrophytes, and undercut banks/root mats.
4 Estimation of riffle embeddedness, or the degree which a riffle's larger inorganic substrate is buried by sand and silt. The higher the score, the less embedded.
5 See Section 3.2.4 for a list of component factors.
6 See Section 3.2.4 for description. Seasonally corrected scores are presented for EPT Richness and Biotic Index.
* Sampled with Qual 4 method (EPT method for 1997 sample). Impacted, but too small to rate.

Mud Creek

- *Mud Creek at Walnut Cove Rd.* This site was sampled in October 2000 and 2001. This site was characterized by a thin riparian zone of trees and shrubs and banks with some erosion potential. It had the rockiest substrate of all Mud Creek sites (35-40% gravel, rubble, or boulder), but riffles were embedded. It also had the most in-stream organic microhabitat, with plenty of sticks, leafpacks, and large woody debris. Although this site had some evident habitat problems, it had the best habitat in Mud Creek (mean of 60 out of 100 total points). It was also characterized by the best biological condition in Mud Creek, with high EPT richness (22 to 23) for a small stream and a moderate BI (4.65 to 4.82). It was characterized by a mix of pollution intolerant and tolerant invertebrates. Long-lived pollution-sensitive stoneflies were present. Although this site could not be rated due to its small size, **the biological community was characteristic of non-impaired mountain streams.**
- *Mud Creek at Berea Church Rd.* The habitat score of this site dropped by an average of 20 points from that at Walnut Cove Rd. Its riffles were more embedded than those of the upstream site, and it had more sand and silt (average of 85%). It had less in-stream microhabitat, with less woody debris and fewer root mats. This incised stream is bermed on both banks, and the banks are covered in some shrubs and grasses. In July 2000, the benthic community showed much improvement from 1997, EPT richness increasing from 2 to 16. Between July and October 2000, the benthic community was likely impacted by a toxic event; in October 2000, EPT richness dropped back down to 5 and was much lower than that 1 mile upstream. Several midge taxa tolerant of toxicity were found at this site, but not at the upstream site. By October 2001, EPT richness was back up to 15, but still likely impacted by toxicity. For all three samples, the community was much more tolerant than that just one mile upstream at Walnut Cove Rd., with BI ranging between 5.96 and 7.07. This site was not rated due to its small size, but **it was characterized by a community exposed to periodic toxic stress.**
- *Mud Creek at Erkwood Rd. above Shepherd Cr.* This site is characterized by excessive amounts of sand (80%) and no riffles. It did have a diversity of organic microhabitat, likely due to the thin band of riparian forest that bordered the site. This site was sampled only once in October 2001 to isolate impacts from the rural part of the drainage from the urban area. It was characterized by a stressed benthic community with an EPT richness of 11 and a BI of 6.69, and toxicity-intolerant stoneflies were absent. **This site was rated Fair, and showed a distinct decline in biological integrity from the upstream site at Berea Church Rd.**

4.3.2 Summary of Conditions and Nature of Impairment

Upper Mud Creek showed signs of increasing stress from upstream to downstream. The uppermost site at Walnut Cove Rd. was stable, maintaining a benthic community characteristic of non-impaired mountain streams. However, at Berea Church Rd., which is 1 mile downstream and below a set of tomato fields, the benthic community showed signs of toxic stress, and the community was severely impacted by a toxic event between July and October 2000. Further downstream at Erkwood Rd., below the Crooked Creek Golf Course and more tomato fields, the benthic community was rated Fair, characterized by a community tolerant of multiple types of stress.

Habitat was limited throughout upper Mud Creek, with high amounts of sand and embedded riffles. Where the riparian vegetation included trees, organic microhabitat was more common.

The habitat was best at the upstream site, which had higher gradient and a wider riparian zone of mixed trees and shrubs.

4.4 Characterization of Chemical and Toxicological Conditions

4.4.1 General Water Quality Characterization

pH fluctuated at the integrator location at Erkwood Rd., ranging between 5.8 and 7.6 standard units (Table 4.3). Specific conductance at the integrator site (42 to 56 µS/cm) was high compared to that of forested mountain streams (Caldwell, 1992). **Fecal coliform bacteria levels were above the NC standard of 200 colonies/100 mL**; the geometric mean of 5 samples collected over 30 days was 231 colonies/100 mL. Dissolved oxygen levels were adequate for aquatic life, but nutrient levels were high compared to forested mountain streams (Simmons and Heath, 1982). Although total phosphorus measured five times during this study in 2001 had a median of below the detection limit of 0.02 mg/L, monthly VWIN data (orthophosphate as P) reveal higher levels for 2000 and 2001 at Erkwood Rd.; median phosphorus was 0.03 mg/L (Table B.12, Appendix B). Phosphorus (in orthophosphate) measured by VWIN at Berea Church Rd. was even higher, with a median of 0.05 mg/L. Baseflow total nitrogen measured during this study had a median of 0.9 mg/L, which is higher than that expected for unpolluted streams in the mountains (Simmons and Heath, 1982).

Table 4.3 Water Quality Results for Mud Creek at Erkwood Road below Shepherd Creek (MUMC01)

PARAMETER	BASEFLOW				
	N	MAX	MIN	MED	MEAN
Nutrients (mg/L)					
Ammonia Nitrogen	4	0.1	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen	5	1.4	0.4	0.6	0.7
Nitrate+Nitrite Nitrogen	5	0.54	0.27	0.50	0.43
Total Nitrogen	5	1.9	0.9	0.9	1.2
Total Phosphorus	5	0.04	<0.02	<0.02	<0.02
Other Conventional					
DO (mg/L)	5	11.6	7.6	8.7	9.1
pH (Standard Units)	5	7.6	5.8	7.1	6.9
Specific Cond (µS/cm)	5	56	42	48	49
Hardness, total (mg/L)	5	20.0	12.0	15.0	15.6
Total Suspended Solids (mg/L)	5	10.9	3.0	6.2	6.3
Total Dissolved Solids (mg/L)	5	95	38	43	52
Turbidity (NTU)	5	6.8	2.6	4.5	4.5
Calcium (mg/L)	6	5.64	2.94	3.59	3.83
Magnesium (mg/L)	6	1.58	0.96	1.09	1.15
Fecal Coliform Bacteria (col/100 mL)	5	460	120	220	231[1]

[1] Mean value for fecal coliform bacteria is the geometric mean.

4.4.2 Stressor and Source Identification: Pesticides

Sediment and water quality sampling was performed on Mud Creek at Erkwood Rd. in order to integrate impacts from the rural part of the subwatershed. **Sediments and SPMDs provided evidence of pesticide inputs to Mud Creek.**

Bed sediment from Mud Creek at Erkwood Rd. above Shepherd Creek tested negative for chronic toxicity using *Hyallela azteca*. Chemical analysis of sediment detected no polycyclic aromatic hydrocarbons, polychlorinated biphenyls, or other semi-volatile organic contaminants. A diverse set of pesticides was found in the sediment, including organochlorine pesticides and more recently developed pesticides (Table 4.4; Mud Creek at US 25 data [MUMC34] are discussed in Section 7). Among organochlorine pesticides, DDE, sum of DDTs, alpha- and gamma-chlordane, and heptachlor were all found at levels within the conservative benchmark range, indicating that it is possible but not probable that these pesticides singly cause toxicity. A number of current use pesticides, including chlorothalonil, chlorpyrifos, esfenvalerate, lambda-cyhalothrin, prometryn, and simazine, were detected in the sediments, but no contaminant, other than chlorpyrifos (for which the benchmark is four times the measured level), has sediment quality benchmarks for comparison. Sediments from a reference stream, the South Mills River, were also sampled; these sediments had some organochlorine pesticides, but only gamma-chlordane was present at levels above conservative benchmarks. Due to the nature of land use in the reference site's watershed (US Forest Service land), current use pesticides were not analyzed.

Table 4.4 Pesticides Detected in the Depositional Sediment of Mud Creek at Erkwood Road above Shepherd Creek (MUMC50), Mud Creek at US 25 (MUMC34), and a Reference Stream, South Mills River (MRSM01)[1]

Contaminant	**Sample Site**			**Benchmark Reference[2]**		
	MUMC50	MUMC34	MRSM01	EPA Region 4	Conservative	Non-Conservative
ORGANOCHLORINE PESTICIDES (ppb) (Dry Weight)						
alpha-chlordane[3]	**1.20**	**0.72**	bdl	0.5	0.5 to 7	4.79 to 49.8
gamma-chlordane[3]	**4.80**	**1.85**	**0.74**	0.5	0.5 to 7	4.79 to 49.8
4,4'-DDD	bdl	bdl	0.26	1.2	0.5 to 7	7.81 to 49.8
4,4'-DDE	**2.74**	**2.10**	0.91	2.07	1.42 to 5	6.75 to 374
sum of DDTs	**2.74**	**2.10**	1.17	1.58	1.58 to 7	41.5 to 4450
heptachlor	**0.72**	bdl	bdl		0.3	8.3
trans-nonachlor	0.95	0.47	bdl			
chlorothalonil	1.60	bdl	NA			
OTHER PESTICIDES (ppb) (Dry Weight)						
chlorpyrifos	11.40	bdl	NA		43.99	
esfenvalerate	41.00	bdl	NA			
lambda-cyhalothrin	27.00	bdl	NA			
prometryn	2.40	bdl	NA			
simazine	1.60	bdl	NA			

1 Values in bold are greater or equal to at least one benchmark. Bdl = below detection limit. MUMC50 and MUMC34 sampled on 10/8/01, and MRSM01 sampled on 8/10/01. NA = not analyzed.
2 Where appropriate, non-conservative benchmarks were adjusted for the lowest total organic carbon value for Mud Creek—0.83% (the TOC for MUMC50). Value for chlorpyrifos is the chronic sediment benchmark from the New York State Department of Environmental Conservation, adjusted for TOC of 0.83%.
3 Benchmark values are for chlordane.

Pesticide analyses (NCSU's broad scan, quantitative GC/MS, and HPLC pesticide analyses) and acute toxicity bioassays were performed on three stormflow samples from Mud Creek at Erkwood Rd. above Shepherd Creek. None of the analyzed pesticides were detected in any sample. **Acute toxicity was found in a sample taken in September 2001, with an LC_{50} of 35%.** Organic compounds used in plastics, including phthalates, bis-phenols, and nonylphenol, were found through a NIST/EPA/NIH library scan (see Section 1.2.1 in Appendix B for details) of the water sample at 0.5 to 10 µg/L (laboratory could not further quantify levels of these contaminants), which are generally well below acute median lethal concentrations for these contaminants.

An SPMD deployed for one week in July 2002 was analyzed with NCSU's broad pesticide scan (Table B.4, Appendix B). Three pesticides were measured on the SPMD—benzothiazole (component of compounds used as wood preservatives and an additive in rubber tires and asphalt), terbutol (herbicide no longer registered for sale), and bifenthrin (insecticide used on row crops, on ornamental plants, lawns, and as a structural termite treatment). There are no comparative screening levels found in toxicological literature for terbutol, but estimated SPMD concentrations of bifenthtrin and benzothiazole are several orders of magnitude below effects levels reported in the literature (see discussion in Appendix B).

4.4.3 Stressor and Source Identification: Metals

Selected metals concentrations measured in the watershed were compared to the chronic and acute EPA NAWQC and Tier II criteria (screening values) that were adjusted for mean hardness (Table 4.5; Table B.12, Appendix B for VWIN data). The copper level for one stormflow event in Mud Creek at Erkwood Rd. is equal to EPA's acute benchmark, but the baseflow median is below the chronic benchmark. VWIN median copper concentration for 2000-2001 is also below the chronic benchmark, but 6 of 22 samples exceed the chronic benchmark for copper. Other metal concentrations were generally below benchmark levels; 1 of 6 DWQ baseflow samples was above the chronic benchmark for zinc, and 1 of 22 VWIN samples and 2 of 6 baseflow DWQ samples were above the chronic benchmark for lead. VWIN data show an increase in median concentrations for copper, lead, and zinc from Berea Church Rd. to Erkwood Rd.

North Carolina has standards or action levels for the protection of aquatic life for some metals. In general, these values are higher than chronic and acute EPA criteria adjusted for hardness. Most individual metal values from VWIN and DWQ samples from Mud Creek at Berea Church and Erkwood Rds. were below the NC's standards or action levels. One of six DWQ baseflow samples was above the NC benchmark for silver or lead.

Data from the French Broad River at Rosman (DWQ station number 03439000) provide a comparison for selected metals. Benthic macroinvertebrates at this site were sampled in 1997 and rated as Excellent; thus metals concentrations likely do not negatively impact the macroinvertebrate community in the French Broad River. Median copper (3 µg/L) in the French Broad River is higher than baseflow medians calculated for data collected in this study (1 µg/L) and by VWIN (1.3 µg/L) in Mud Creek. Median zinc levels are notably higher in the French Broad River at Rosman.

Metals analyzed in sediment from Mud Creek at Erkwood Rd. were at concentrations below sediment benchmarks (Table B.5, Appendix B).

Table 4.5 Selected Metals in Mud Creek and Comparison Values of the French Broad River at Rosman and EPA Screening Levels[1, 2, 3]

Site	Total Metal Concentration (µg/L)					
	Cadmium	**Copper**	**Lead**	**Silver**	**Zinc**	**Calculated Hardness (mg/L)[4]**
NCDWQ Class C Standard	**2.0**	**7**	**25**	**0.06**	**50**	
<u>Mud Creek at Erkwood Rd.</u>						
(MUMC50) above Shepherd Cr.						
3/12/2001--stormflow	<0.1	**2**	<1	<0.5	5.1	10.4
Adjusted acute benchmark	0.4	2	5	0.1	17.6	
(MUMC01) below Shepherd Cr.						
Baseflow median (n=6)	<0.1	1	<1	<0.5	2.3	13.4
Adjusted chronic benchmark	0.5	2	0.2	0.4	21.8	
<u>French Broad River at Rosman:</u>						
median of 53 samples collected between 1/93 and 12/97		**3**			16.0	

1 Baseflow values and French Broad River medians ≥ the chronic benchmark and stormflow values ≥ the acute benchmark are in bold type. If the value was < the DL, it is listed as "<DL".

2 Chronic and acute benchmarks for all metals except Ag are EPA NAWQC values. Those for Ag are EPA Tier II Values. Benchmarks were adjusted for site-specific hardness.

3 Metals listed are those with at least one sample from the Mud Creek watershed above the screening level.

4 Hardness calculation=([Ca^{2+}] X 2.497) + ([Mg^{2+}] X 4.118). Data not available for French Broad River.

4.4.4 Stressor and Source Identification: Suspended Sediment

Suspended sediment concentrations (SSC) measured during five storms at Berea Church Rd. were consistently among the highest in the Mud Creek watershed, including one at 3,416 mg/L in July 2001. This site had a median SSC concentration of 510 mg/L. See Section 2.2. in Appendix B for more information.

4.5 Channel and Riparian Area

The entire length of Mud Creek was walked from Walnut Cove Rd. to the confluence with Shepherd Creek at Erkwood Rd., and riparian and channel conditions were observed. More cursory examinations of stream and riparian conditions were performed for many of the tributaries of upper Mud Creek; small sections of some tributaries were surveyed more intensively.

<u>Channel and riparian area description</u>
Upper Mud Creek is an unstable system with a wide floodplain, from which it is likely disconnected except during large flood events. It has been channelized in many areas, but channelization is most evident and extreme in the 2 mi just upstream of Erkwood Rd., where the

stream is wide, straight, and closely paralleled by power lines (Figure 4.2). Mud Creek is incised, likely due to historic channelization, removal of woody riparian vegetation, and subsequent downcutting through the substrate. Mud Creek may be in a stage of channel widening (NCSU, 2001b). Incised streams that have begun widening generally continue to do so until the channel width is sufficient to allow for the stabilization of slumped banks and the development of a new geomorphic floodplain within the banks (Schumm et al., 1984; Simon 1989; Simon and Darby, 1999).

For most of its length between its headwaters at Camp Blue Star and Erkwood Rd. (approximately 7 mi), upper Mud Creek flows through pasture, crop land and golf course. In some crop areas, the banks are diked to protect against flooding. Corn, ornamental plants, tomatoes, and peppers are grown along Mud Creek. Tomato and pepper fields are irrigated with water pulled from the creek and passed through a drip irrigation system. In pastureland, cattle were often fenced out of the creek, but there were still some places where cattle have access to Mud Creek, causing severe bank instability.

Duke Energy power transmission lines follow this part of Mud Creek for almost 5 mi between Walnut Cove Rd. and Erkwood Rd., coming within 25 ft of the creek. In 2001, a mix of the herbicides Accord® and Arsenal® (which is not licensed by EPA for use over water) was applied to the right-of-way beneath transmission lines in the watershed. No spraying was performed in 2000. Where lines closely paralleled the creek or where they crossed the creek, riparian and bank vegetation has been eliminated or severely limited. Stream banks have failed at some power line crossings.

As Mud Creek flows through agricultural and golf course areas, riparian vegetation is generally limited to a thin (0-10 ft) border of a mix of invasive shrubs and herbaceous plants that do not provide much bank stabilization. These unstable banks are prone to sloughing, and recent and older bank blowouts were observed. Recent blowouts were seen in areas where cattle have stream access and at power line crossings (Figure 2.16). In some areas, landowners have attempted to stabilize unstable banks with tires, wood, and other materials. Where the channel is wider due to blowouts, the stream has more room to meander through the incised channel. Bare banks are likely a major source of excess sediment seen in the channels.

Figure 4.2 Channelized reach in upper Mud Creek.

In-stream habitat

Lack of riparian vegetation not only impacts stream bank stability, but in-stream habitat, as well. A direct impact of this is a lack of large woody debris, sticks, leafpacks, and suitable edge habitat (tree roots). Stream temperature also increases due to the lack of riparian vegetation. An indirect impact is an increase in sedimentation due to bank instability. In the infrequent areas where a wider riparian forest is still present on both sides of the creek and the creek had some natural sinuousity, the quality of in-stream habitat is notably better, with wood, leafpacks, and riffles present.

Stream substrate is dominated by sand and silt, likely driven by the low gradient of Mud Creek and inputs of this fine sediment. Stream surveys pinpoint eroding stream banks, roads and driveways, and construction sites as the most notable sources of sediment. Another notable source of sediment was from a dam breach in the Flat Rock Lakes development; the breach filled a Mud Creek tributary with a large amount of sand. Closer to the headwaters, there is more large substrate, such as cobble. There are a number of notable nickpoints composed of bedrock shelves that serve as grade controls upstream of Erkwood Rd., stopping any upstream movement of incision. There are infrequent riffles in Mud Creek, often in areas of disturbance (blowouts) where there was more sinuousity within the channel; where the creek is straight, the only riffles present are at bedrock nickpoints.

Tributaries

Higher gradient tributaries are generally characterized by much better in-stream habitat. Most of these streams were not channelized and often have a healthy buffer of riparian vegetation. Fine sediment from roads and upland construction is pushed through these streams down to low gradient areas. Once tributaries are in lower gradient areas, they often have issues similar to those of Mud Creek—channelization, little riparian vegetation, incision, and heavy amounts of sand and silt.

4.6 Conclusions: Identification of Causes and Sources of Impairment

Mud Creek is impaired downstream of Walnut Cove Rd. Based on benthic community monitoring data collected during this study, Mud Creek above Walnut Cove Rd. is not impaired although it is impacted by habitat degradation. Each stressor investigated during this study is evaluated below. See Section 3.5.1 for definitions of stressor types (e.g., cumulative cause of impairment).

4.6.1 Habitat Degradation Due to Sedimentation

Sedimentation is a cumulative cause of impairment.

Excess sediment deposition was evident at all benthic monitoring sites on Mud Creek, although it was most problematic at those sites with the most impacted biological communities. Although sand and silt were the dominant substrates at the uppermost site at Walnut Cove Rd., coarser substrate (cobble and gravel) were still present in substantial amounts. At all lower sites, sand and silt increased to 80-90% of the substrate and riffle embeddedness increased. *Sedimentation is considered a cumulative cause of impairment for upper Mud Creek.*

Sediment sources. Excess sediment deposition was notable throughout Mud Creek. Sources of sediment are numerous and come from both in-stream and upland sources. Unstable and unvegetated banks of Mud Creek and its tributaries are an important source of sediment. Mud Creek and some of its tributaries are incised and laterally unstable. These creeks have likely downcut to lower bed levels. Various sections of the creeks have been channelized, which is often accompanied by incision. The practice of clearing bank vegetation further destabilizes stream banks. Exposed loose soil erodes into streams during storm events, increasing suspended and bed load sediments.

Upland sources of sediment are important in this watershed as well. High suspended sediment levels were found in the upper part of the watershed, where a number of sources were evident. Home and road development, established home sites with eroding slopes, unpaved roads and driveways, dam failure, and eroding road banks provide sources of sediment. Unpaved roads and driveways in the headwaters area near Pinnacle Mountain appear to be especially problematic due to steep grade.

4.6.2 Habitat Degradation--Other Issues

Lack of organic microhabitat and lack of a diversity of depth and velocity combinations (riffles, pools, bends) are cumulative causes of impairment.

Although not considered at the onset of this study, other watershed-wide issues contribute to habitat degradation in Mud Creek. Extensive channelization over the past 150 years has led to channel "simplification"—a straighter channel with few bends, riffles, and pools. Conversely, meandering channels generally have a diversity of depth and velocity types, providing key habitats for aquatic organisms. Within a meandering channel, this diversity of depth and velocity provides channel roughness, or irregularity, that is important in catching organic microhabitats, such as sticks and leaves. In areas where the stream channel did meander below stream bank blowouts or within a less controlled channel, riffles and pools were more frequent.

Limited riparian vegetation was an issue for much of upper Mud Creek. In many agricultural areas, vegetation was limited to a thin fringe of invasive shrubs and herbaceous vegetation. This vegetation does provide a source of sticks and leafpacks important for benthic macroinvertebrates. However, undercut banks and large woody debris provided by trees were limited. Undercut banks and large wood not only provide habitat and a food source for aquatic organisms, but they also contribute to channel roughness, catching smaller organic microhabitats.

These habitat issues likely act in concert with sedimentation to impact the aquatic community. *Lack of suitable in-stream habitat, including organic microhabitat and a diversity of depth and velocity combinations (riffles, pools, bends), is considered a cumulative cause of impairment.*

4.6.3 Toxicants

> Exposure to toxicants is a primary cause of impairment, and pesticides are the most likely toxicants for the Berea Church Rd. area.

Benthic community analysis and toxicity test failure provide evidence of periodic toxic inputs to upper Mud Creek. The benthic community downstream of Walnut Cove Rd. demonstrated two typical characteristics of toxic stress: 1) toxicant-intolerant taxa, such as stoneflies, were typically absent and more tolerant taxa were dominant; and 2) at the site that was sampled multiple times during the study (Berea Church Rd.), ecological index scores periodically plummeted and rose, indicating cyclical stress and recovery.

Benthic monitoring bracketed greater than 10 acres of tomato fields (see Section 2.5.2) that covered much of the land along the south bank of Mud Creek between Walnut Cove and Berea Church Rds. In 2000, benthic community data indicated that a toxic event occurred between July and October (during the tomato growing season) in the mile of stream between Walnut Cove and Berea Church Rds. Sampling in October 2001 also indicated toxic stress between the two roads, and signs of increasing stress were seen in the benthic community further downstream at Erkwood Rd.

Erkwood Rd. is just below a large tomato farm (approximately 25 acres) and the Crooked Creek Golf Course. Although sediments from Mud Creek at Erkwood Rd. passed sediment toxicity tests, they contained a number of pesticides. Organochlorine pesticides were found at levels above conservative screening benchmarks, indicating that it is possible but not probable that they cause sediment toxicity. Most organochlorines found (DDD, heptachlor, chlordane, trans-nonachlor) were banned in the 1970s and are likely from past use. Current use pesticides, including esfenvalerate (insecticide used on tomatoes, corn, and fruit trees), chlorpyrifos (organophosphate insecticide used on crops, lawns, and in houses), simazine (herbicide used on crops, turf, ornamentals, and orchards), chlorothalonil (organochlorine fungicide used on tomatoes, other vegetables, trees, turf, and ornamentals), lambda-cyhalothrin (insecticide used on tomatoes, other vegetables, grains, and ornamentals), and prometryn (herbicide used on crops), were also found in sediments. Only chlorpyrifos had a comparative benchmark, which was higher than the measured sediment concentration. The other pesticides have no published benchmarks for comparison; therefore, the toxic potential of observed concentrations of these compounds is uncertain. In addition, sediment benchmarks only address the singular impacts of contaminants; comparison of contaminant levels to benchmarks does not address cumulative toxicological effects of multiple contaminants.

In one out of three of the stormflow events sampled, a bioassay indicated that acute toxicity was present in the water column in Mud Creek above Erkwood Rd. and its confluence with Shepherd Creek. None of the pesticides measured by the full pesticide scan were detected; however, there are no analytical methods for many current use pesticides (e.g., of the seven most commonly used tomato insecticides and fungicides listed in Section 2.5.2, only four could be analyzed). It is possible that toxicity during this storm was due to one of these pesticides or to pesticide breakdown products, but this cannot be evaluated with the data available.

Based on land use between Walnut Cove and Berea Church Rds. and the possibility of pesticide inputs from tomato fields, the most likely toxicants for the site on Berea Church Rd. are tomato pesticides. Delivery of tomato and pepper pesticides can be from stormflow runoff (which may account for the toxicity at Erkwood Rd. in September 2001), backflow siphoning in poorly designed irrigation-fertilizer-pesticide delivery systems, backwash from the same systems, and spills in mixing areas, which are often near streams. A number of insecticides typically used on tomatoes and peppers (esfenvalerate, endosulfan, lambda-cyhalothrin, cyfluthrin) are highly toxic to aquatic organisms (EXTOXNET Pesticide Information Profiles at http://ace.orst.edu/info/extoxnet/). No other likely sources of pesticides exist between Walnut Cove and Berea Church Rds.—there are no golf courses and Duke power line spraying only occurred in 2001. In addition, point sources are not a likely source of toxicity here, since the only point source (Camp Blue Star) is above Walnut Cove Rd. and would impact the upper site as well as the Berea Church Rd. site.

Erkwood Rd., which is four miles below Berea Church Rd., may also be impacted by tomato pesticides, but other pesticides and toxicants are possible as well, possibly coming from the golf course, Duke's power line spraying, other agricultural crops, and residential areas.

Based on analysis of benthic macroinvertebrate data, exposure to toxicants is considered a primary cause of impairment for upper Mud Creek. Tomato pesticides are the most likely toxicants for the Berea Church Rd. area based on analysis of potential sources.

4.6.4 Other Possible Stressors

The extended drought that began mid-1998 decreased flows in the Mud Creek watershed, with annual rainfall approximately three-fourths the annual mean. Low flows themselves can stress aquatic invertebrate communities by shrinking aquatic habitat (e.g., isolating edge habitat) and changing energy dynamics (e.g., slowing the current in riffles). Many studies have demonstrated substantial changes in benthic community composition due to drought (e.g., Canton et al., 1984; Cowx et al., 1984). The impacts of other stressors such as non-storm driven pollutants are likely magnified by low flows, since these are more concentrated with less stream volume. However, storm-driven nonpoint source impacts are likely reduced with lower flows. Flow-influenced impacts that occurred during this two-year study period are likely atypical. However, it is unlikely that low flows are a key stressor; reference sites in the adjacent Crab Creek watershed sampled during the same period (see Sections 5.3 and 6.3) were rated Good or Excellent.

Copper levels in Mud Creek were infrequently above screening benchmarks; however, similar levels were measured in a reference stream with an Excellent benthic community, the upper French Broad River. It is unlikely that copper is a cause or contributor of impairment. Likewise, plastic degradation compounds, including phthalates and nonylphenol, were found in a storm sample at levels that are below published acute toxicity levels, so it is unlikely that they are a cause or contributor of impairment.

High fecal coliform bacteria levels were found in upper Mud Creek. Although these can indicate a risk to human health, they do not directly impact biological community condition. The most likely sources of these high levels were cattle that had access to Mud Creek and its tributaries.

4.6.5 Conclusion

A number of stressors act in concert to impact upper Mud Creek. Exposure to toxicants is considered a primary cause of impairment, and based on an analysis of sources, the most likely toxicants are tomato pesticides at Berea Church Rd. Habitat degradation due to sedimentation and lack of suitable in-stream habitat, including organic microhabitat and a diversity of depth and velocity combinations (riffles, pools, bends), are considered cumulative causes of impairment.

Section 5
Results and Conclusions:
Clear Creek and Devils Fork Subwatersheds

The entire length of Clear Creek is considered impaired, and Devils Fork has not previously been rated. DWQ's Biological Assessment Unit has performed two studies in the Clear Creek watershed prior to the current study. In 1977-78, the Clear Creek mainstem and a tributary, Cox Creek, were sampled intensively (Penrose and Lenat, 1982). Increasing impacts to the benthic community (e.g., decreased EPT richness, loss of stoneflies) in an upstream-downstream direction were linked to increasing area of apple orchards in the watershed. Likewise, a study performed in 1993 (NCDWQ, 1993) linked similar benthic impacts in Clear Creek and its two tributaries, Cox and Puncheon Camp Creeks, to apple orchards.

Prior to this study, little was known about the present state of the fish community in the Clear Creek subwatershed. Part of Clear Creek and many of its tributaries are classified as trout waters, and data from the 1960s provide evidence of rainbow trout in Clear Creek and some of its upper tributaries (Scott Loftis, NC Wildlife Resources Commission, personal communication). Tennessee Valley Authority biologists sampled fish in Clear Creek at a downstream site in 1997 and rated the community as Fair.

The Volunteer Water Information Network (VWIN) samples at two sites on the Clear Creek mainstem and one on Devils Fork. Prior to this study, downstream increases in metals, nutrients, and sediment were noted in Clear Creek. Devils Fork had high nutrient and turbidity levels.

5.1 Key Stressors Evaluated in the Clear Creek and Devils Fork Subwatersheds

Plausible causes of biological impairment in the Mud Creek watershed were identified using both bioassessment and watershed-driven approaches (Figure 1.2). Biological community data, habitat information, and land uses and activities were considered to flag stressors for further investigation. Based on preliminary review, the following stressors were evaluated as the most plausible candidate causes of impairment in Clear Creek and Devils Fork for further investigation:

1. <u>Pesticides</u>. Pesticides used on apple orchards have long been suspected as a cause of toxicity in Clear Creek and its tributaries. There are other sources of pesticides as well, including large areas of corn, drip irrigated crops such as tomatoes, peppers, and squash, and residential areas.

2. <u>Habitat degradation due to sedimentation</u>. Habitat degradation due to sedimentation manifests itself in the loss of pools, burial of riffles, and high levels of substrate instability.

5.2 Monitoring Locations

Monitoring site locations as listed below were chosen in order to characterize stream integrity, identify stressors, and pinpoint sources of these stressors. Due to the past studies that linked benthic invertebrate community impacts to apple orchard areas and the changing nature of apple growing in Henderson County (e.g., changes in pesticide use, decreased amount of land in apple orchards), benthic sites were chosen to assess present conditions in streams below apple orchards. Integrated Pollutant Source Identification land use/cover data were used to determine apple orchard area in the subwatersheds (see Section 2). Benthic invertebrate communities, fish communities, water chemistry, and sediment chemistry were evaluated in this study primarily during the period of 2000-2001 (Figure 5.1, Table 5.1). VWIN chemical data were also used in this analysis.

<u>Clear Creek Mainstem (Upstream to Downstream)</u>
All mainstem sites are below apple orchards, cattle pasture, and recent development.

- *Clear Creek at N. Clear Creek Rd. (SR 1591)* (MUCC36). This is the furthest upstream benthic monitoring site on Clear Creek. It was sampled during a 1993 benthic study, when it was characterized by limited EPT richness.
- *Clear Creek at Bearwallow Rd. (SR 1587)* (MUCC37). This site is below a few small row crop areas. This site is below Cox Creek, and it was sampled during the 1977-78 and 1993 (when it was rated Fair) benthic studies. It was sampled for benthos and fish.
- *Clear Creek at Apple Valley Rd. (SR 1572)* (MUCC38). This site is below a few small row crop areas and is a VWIN monitoring site.
- *Clear Creek at Mills Gap Rd. (SR 1586)* (MUCC48). This site is below some row crop areas along the Clear Creek mainstem. This is a benthic monitoring site that was sampled in 1993, and it was rated Fair. Sediment samples were collected at this location for toxicity and chemistry analyses, and the fish community was also monitored.
- *Clear Creek at Townsend Rd. (SR 1578)* (MUCC27). This site is below row crop areas along the Clear Creek mainstem and Lewis Creek. Samples were collected for pesticides.
- *Clear Creek at Nix Rd. (SR 1513)* (MUCC19). This site is below row crop areas along the Clear Creek mainstem and throughout the watershed. It was sampled for benthos in 1992 and 1997, and it was consistently rated Poor. It was sampled for benthic macroinvertebrates, fish, sediment chemistry and toxicity, water toxicity, and pesticides. This is also a VWIN site.
- *Clear Creek at Clear Creek Rd. (SR 1503)* (MUCC04). This site is below row crop areas along the Clear Creek mainstem and throughout the watershed. This site is the integrator location for the Clear Creek subwatershed, at the lowest road crossing before Clear Creek's confluence with Mud Creek. It is downstream of many new subdivisions. Samples were taken for suspended sediment, integrator parameters, and pesticides.

<u>Clear Creek Tributaries</u>

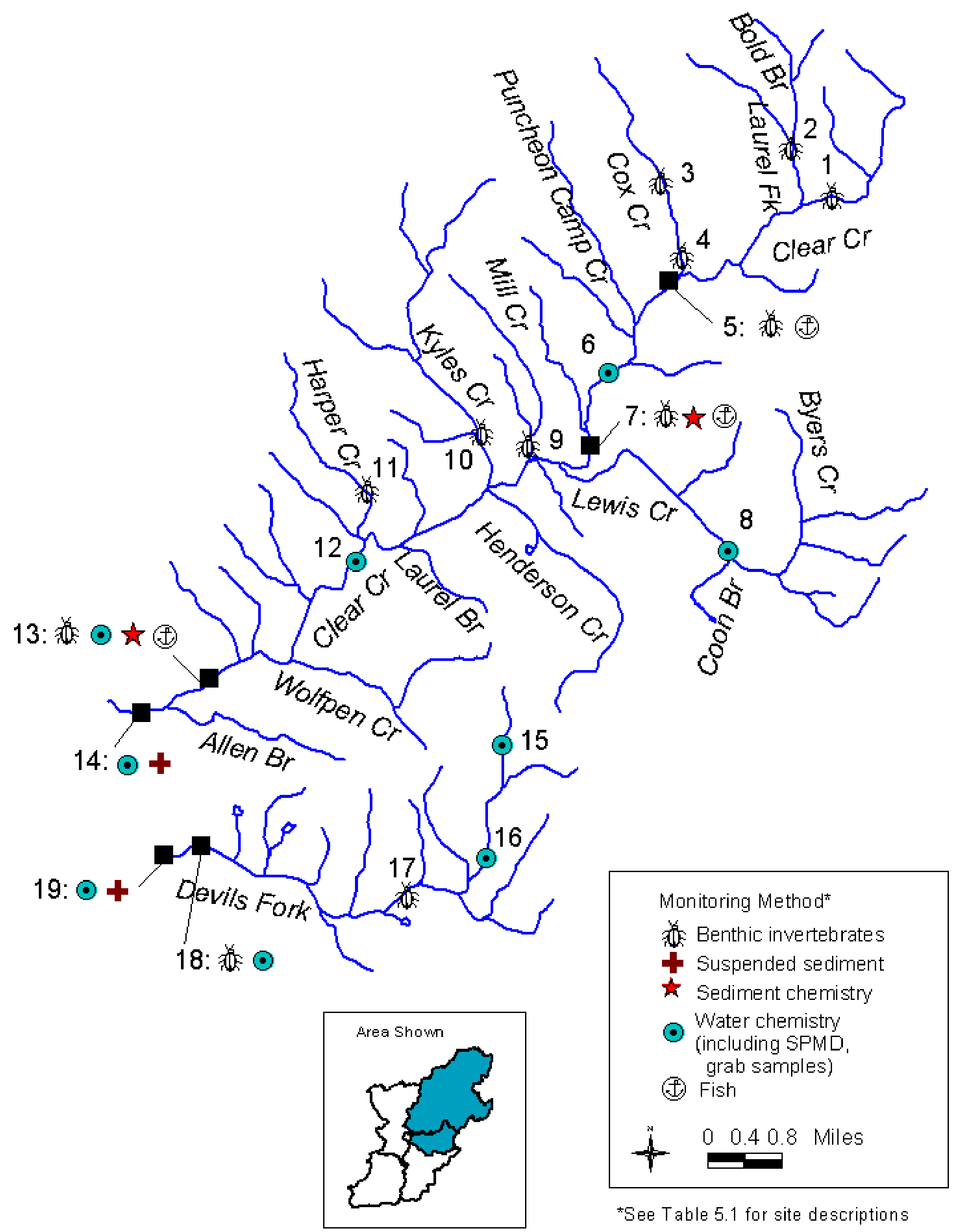
- *Cox Creek at Bearwallow Rd. (SR 1587)* (MUCX39). This site was sampled during the 1977-78 and 1993 benthic studies, showing decreased EPT richness from its upstream reference. It is below orchards and residential development. It was sampled for benthic macroinvertebrates.

Table 5.1 Summary of Monitoring Approaches Used at Primary Sampling Sites, Clear Creek and Devils Fork Subwatersheds

	Station Code	Site # in Figure 5.1	Location	Benthos	Fish	DWQ Water Quality[1]	VWIN Water Quality[1]	Suspended Sediment	Bed Sediment Quality
Clear Creek Mainstem	MUCC36	1	*Clear Creek at N. Clear Creek Rd.*	✓					
	MUCC37	5	*Clear Creek at Bearwallow Rd.*	✓	✓				
	MUCC38	6	*Clear Creek at Apple Valley Rd.*				✓		
	MUCC48	7	*Clear Creek at Mills Gap Rd.*	✓	✓				✓
	MUCC27	12	*Clear Creek at Townsend Rd.*			✓			
	MUCC19	13	*Clear Creek at Nix Rd.*	✓	✓	✓	✓		✓
	MUCC04	14	*Clear Creek at Clear Creek Rd.*			✓+		✓	
Clear Cr. Tributaries	MUCX39	4	*Cox Creek at Bearwallow Rd.*	✓					
	MULC28	8	*Lewis Creek at Pilot Mountain Rd.*			✓			
	MUMI40	9	*Mill Creek at Mills Gap Rd.*	✓					
	MUKY41	10	*Kyles Creek at Fruitland Rd.*	✓					
	Reference Sites								
	MULF43	2	*Laurel Fork at Wash Freeman Rd.*	✓					
	MUHC44	11	*Harper Creek at Clear Creek Rd.*	✓					
	MUCX45	3	*Cox Creek at Hickory Acres Rd.*	✓					
Devils Fork	MUDF32	15	*Devils Fork at Blue House Rd.*			✓			
	MUDF31	16	*Devils Fork at Old Dana Rd.*			✓			
	MUDF42	17	*Devils Fork at Howard Gap Rd.*	✓					
	MUDF13	18	*Devils Fork at Tracy Grove Rd./US 64*	✓		✓	✓		
	MUDF03	19	*Devils Fork at 7th Ave.*			✓		✓	
Crab	*Reference Sites*								
	CRCR01		*Crab Creek at Shoal Falls Rd.*				✓		
	CRCR02		*Crab Creek at Island Cove Rd.*	✓	✓				

[1] Grab samples and/or repeated field measurements.
\+ Integrator station.

Figure 5.1 Monitoring Sites in the Clear Creek and Devils Fork Subwatersheds



*See Table 5.1 for site descriptions

- *Lewis Creek at Pilot Mountain Rd.* (MULC28). This site is downstream of significant orchard operations on both sides of the stream and a small amount of row crops. Chemical sampling was performed to assess drift and runoff of orchard pesticides.
- *Mill Creek at Mills Gap Rd. (SR 1586)* (MUMI40). This site is below pasture, residential areas, some row crops, and a large set of orchards. It was a benthic monitoring site.
- *Kyles Creek at Fruitland Rd. (SR 1579)* (MUKY41). This site drains a primarily forested catchment with some residential use, but also has a small set of apple orchards and a tomato field just upstream. It was sampled for benthic macroinvertebrates.

<u>Devils Fork Mainstem (Upstream to Downstream)</u>

- *Devils Fork at Blue House Rd. (SR 1735)* (MUDF32). This site is downstream from significant orchard operations. A sample was collected for pesticide analysis at low baseflow to assess possible pesticide contaminated groundwater recharge into the stream.
- *Devils Fork at Old Dana Rd. (SR 1738)* (MUDF31). This site is downstream from significant orchard operations and row crops. A sample was collected for pesticide analysis at low baseflow to assess possible pesticide contaminated groundwater recharge into the stream.
- *Devils Fork at Howard Gap Rd. (SR 1006)* (MCDF42). This site drains a mix of orchard, row crop, residential, commercial, and pastureland, and it was monitored for benthos.
- *Devils Fork at Tracy Grove Rd./US 64* (MUDF13). This site integrates all watershed orchard operations and row crops and is also below residential and commercial development. One stormflow sample was collected for analysis of toxicity and pesticides. Benthic macroinvertebrates were also sampled. This is also a VWIN site.
- *Devils Fork at 7th Ave.* (MUDF03). This is the lowest road crossing on Devils Fork before its confluence with Mud Creek. It is downstream of orchard and row crops as well as residential land and the business district on US 64. Samples were collected for suspended sediment, integrator parameters, organics, pesticides, and toxicity.

<u>Clear Creek Tributaries: Reference Sites</u>

- *Laurel Fork at Wash Freeman Rd. (SR 1592)* (MULF43). This site was sampled in 1993, and it was rated Excellent. It has a primarily forested watershed and is below some recent residential development. It is a benthic monitoring site. Although there are some apple orchards along the lower segment of Laurel Fork, benthos were sampled above these orchards.
- *Harper Creek at Clear Creek Rd. (SR 1582)* (MUHC44). This site drains a residential forested catchment, and it was monitored for benthos.
- *Cox Creek at Hickory Acres Rd.* (MUCX45). This site drains a forested catchment and was the upper benthic monitoring site on Cox Creek.

<u>Crab Creek: Reference Site</u>

- *Crab Creek at Shoal Falls Rd. (SR 1130)* (CRCR01). This site drains a rural catchment, including residential and row crop uses and has forested headwaters. The mainstem runs through pastureland. It was a VWIN site. See Figure 3.1 for location.
- *Crab Creek at Island Cove Rd. (SR 1532)* (CRCR02). This site drains a rural catchment, including residential and row crop uses and has forested headwaters. The mainstem runs through pastureland, and a tobacco field was located near the sampling site. It was a benthic reference site for Clear Creek. The fish community was also sampled in 2002. See Figure 3.1 for location.

5.3 Characterization of the Biological Community and Stream Habitat

5.3.1 Benthic Monitoring

Benthic monitoring focused on the potential impacts of apple orchard pesticides, with many sites sampled before and after the growing season to assess potential impacts and recovery. Lower Clear Creek mainstem and tributary sites and the upper Devils Fork mainstem site were generally sampled once during the growing season in 2000, then in March 2001 before growing season pesticide applications, and finally at end of the growing season in October 2001. Because a large number of samples were collected at a total of 13 sites during this study, results for specific sampling sites are summarized in Table 5.2, and narrative summaries for each site are given in Appendix A. Some streams were too small to be given a formal rating (bioclassification) (see Section 3.2.2 for additional details), and metric scores (EPT richness, biotic indices) provide information for comparison of sites.

Most benthic sites below a significant area (>100 acres) of apple orchards were severely impacted, exhibiting signs of toxic stress, which include reduced EPT richness, few or no stoneflies, toxicity-tolerant taxa in abundance, and deformities (Figure 5.2). However, some sites were also below row crop areas, which are potential sources of pesticides. In particular, Devils Fork and lower Clear Creek mainstem sites were below considerable row crop activity.

Streams with small catchments that drain significant areas of orchards, including lower Cox Creek, Mill Creek (sampling site also below about 20 acres of streamside row crop farming, mostly corn), and upper Clear Creek (at N. Clear Creek Rd.), were characterized by much lower EPT richness, fewer stonefly taxa, and higher biotic index scores than small stream reference sites (Laurel Fork, upper Cox Creek, Harper Creek).

The Devils Fork mainstem sites and the two downstream Clear Creek sites (Mills Gap and Nix Rds.) had the worst condition of all sites in the Devils Fork and Clear Creek subwatersheds, consistently characterized by the lowest EPT richness and highest biotic index scores. These sites had only one or no stonefly taxa, as opposed to the Crab Creek reference site, which had nine stonefly taxa on both sampling dates. A midge deformity analysis performed on the March 2001 benthic sample from Clear Creek at Mills Gap Rd. indicated severe toxicity. (A deformity analysis could not be performed at other sites because there were too few *Chironomus*, the midge taxon used in the analysis.)

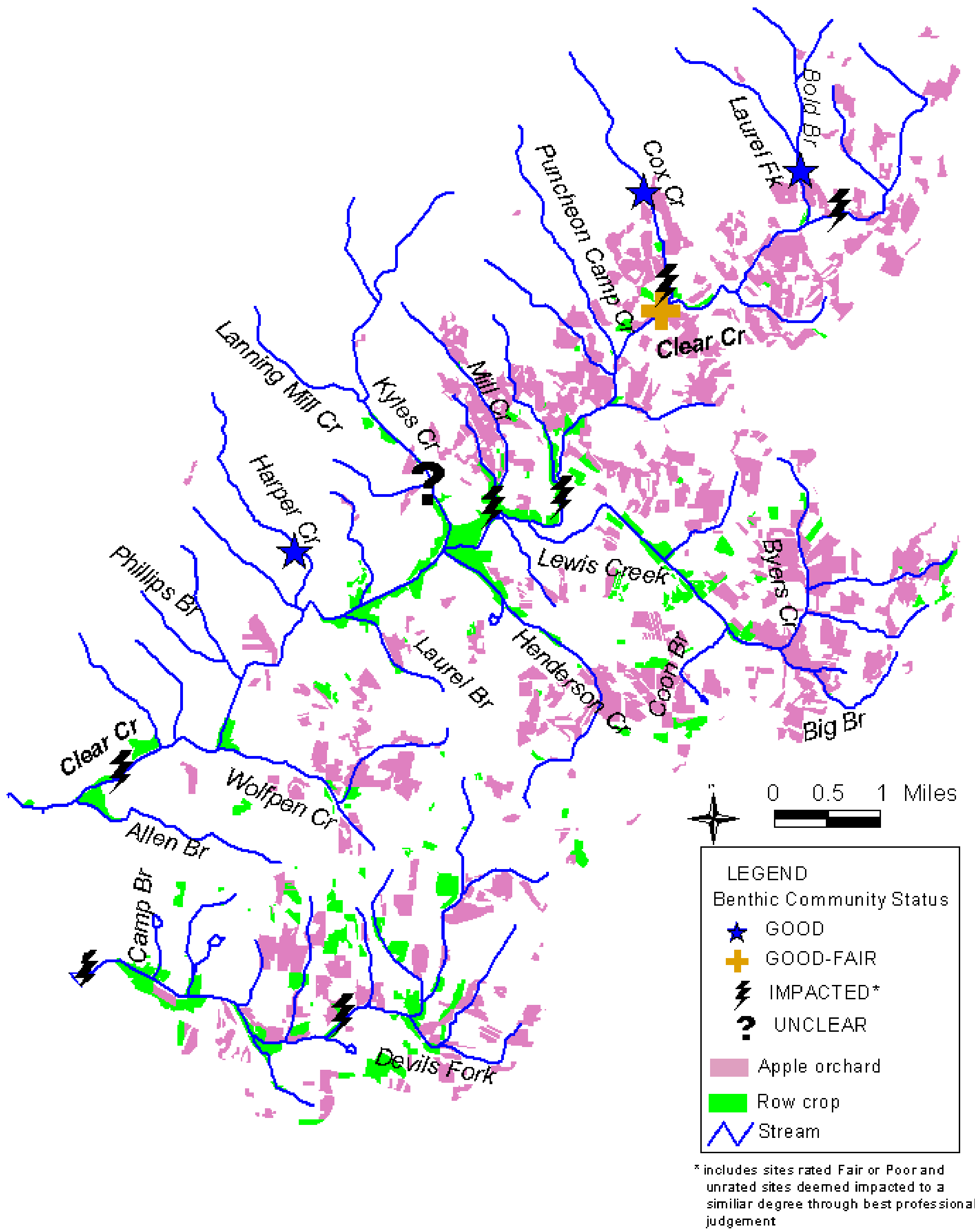
Two sites in this study, Clear Creek at Bearwallow Rd. and Kyles Creek, did not follow this pattern. The Clear Creek site does drain a significant area of orchards and had a benthic community indicative of toxicity in 1993, but the one time it was sampled during this study (October 2000), it had a much higher EPT richness and lower biotic index score than in 1993, leading to a Good-Fair rating. It hosted a much more diverse benthic community than the most upstream site at N. Clear Creek Rd. This recovery is likely due to the upstream tributary of Laurel Fork, which comes into Clear Creek between the two monitoring sites and serves as a high quality source of benthic macroinvertebrates for downstream drift.

Table 5.2 Selected Benthic Community and Habitat Characteristics at Study Sites in the Clear Creek and Devils Fork Subwatersheds[1]

	Site	Draining ≥100 acres of apple orchards	Date	Substrate % sand and silt[2]	In-stream Structure Score (of 20)[3]	Embedded-ness Score (of 15)[4]	Habitat Score Total (of 100)[5]	EPT Richness [stonefly richness in ( )][6]	EPT Biotic Index[6]	Biotic Index[6]	Bioclassification[6]
Clear Creek Mainstem	Clear Creek at N. Clear Cr. Rd.	✓	10/23/00	40	9	6	45	14 (3)	3.82	5.12	Not Rated**
	Clear Creek at Bearwallow Rd.	✓	10/24/00	30	16	10	80	23 (2)	3.29	4.92	Good-Fair
	Clear Creek at Mills Gap Rd.	✓	7/12/00	60	16	13	NA	5 (0)	5.04	6.26	Poor
	"	✓	3/14/01	30	14	13	78	8 (0)	5.07	6.78	Poor
	"	✓	10/03/01	30	20	9	75	4 (0)	6.38	7.24	Poor
	Clear Creek at Nix Rd.	✓	7/12/00	80	11	8	52	14 (0)	5.3	5.96	Fair
	"	✓	10/26/00	60	12	6	42	8 (1)	4.50	5.94	Poor
	"	✓	3/13/01	45	10	8	56	15 (1)	4.47	6.61	Fair
	"	✓	10/03/01	45	16	8	60	10 (1)	5.04	6.57	Fair
Clear Creek Tributaries	Laurel Fork at Wash Freeman Rd.		10/24/00	20	18	12	89	28 (8)	2.70	3.49	Good
	"		10/03/01	25	16	15	91	21 (6)	2.11	3.67	Not Rated*
	Cox Creek at Hickory Acres Rd.		10/23/00	10	16	15	85	22 (7)	2.43	3.60	Good
	Cox Creek at Bearwallow Rd.	✓	10/23/00	10	16	15	73	16 (2)	2.84	5.22	Not Rated**
	"	✓	3/14/01	20	15	15	73	13 (0)	3.16	5.03	Not Rated**
	"	✓	10/03/01	20	14	15	68	14 (0)	4.21	5.67	Not Rated*
	Mill Creek at Mills Gap Rd.	✓	10/23/00	NA	NA	NA	37	11 (1)	4.54	5.30	Not Rated**
	"	✓	3/14/01	50	14	13	55	10 (2)	4.65	6.06	Not Rated**
	"	✓	10/03/01	60	14	11	51	8 (0)	4.27	5.54	Not Rated*
	Kyles Creek at Fruitland Rd.		3/14/01	55	15	13	51	37 (8)	3.01	4.85	Not Rated*
	"		10/03/01	70	14	15	58	17 (1)	3.22	5.12	Not Rated*
	Harper Creek at Clear Cr. Rd.		10/24/00	40	11	4	72	26 (4)	2.68	4.03	Good
Devils Fk	Devils Fork at Howard Gap Rd.	✓	7/13/00	60	10	10	57	8 (0)	5.29	6.06	Not Rated**
	"	✓	10/25/00	70	12	3	50	8 (1)	6.48	6.65	Not Rated**
	"	✓	3/03/01	50	11	10	57	7 (0)	6.24	6.80	Not Rated**
	"	✓	10/04/01	70	12	8	46	4 (0)	5.63	6.20	Not Rated*
	Devils Fork at US 64	✓	7/13/00	100	7	3	17	5 (0)	6.24	7.84	Not Rated**
	Crab Creek at Island Cove Rd.		10/26/00	50	14	11	72	43 (9)	3.62	5.12	Good
			10/03/01	30	16	6	60	30 (9)	4.08	5.37	Good-Fair

1 Sites shaded in grey are reference sites.
2 Based on visual estimate of substrate size distribution.
3 Visual quantification of the of in-stream structures present, including leafpacks and sticks, large wood, rocks, macrophytes, and undercut banks/root mats.
4 Estimation of riffle embeddedness, or the degree which a riffle's larger inorganic substrate is buried by sand and silt. The higher the score, the less embedded.
5 See Section 3.2.4 for a list of component factors.
6 See Section 3.2.4 for description. Biotic index is seasonally corrected.
* Sampled with Qual 5 method, which currently has no rating method.
** Sampled with Qual 4 method. Impacted, but too small to rate.

Figure 5.2. Apple Orchards, Row Crops, and Benthic Macroinvertebrate Communities in the Clear and Devils Fork Subwatersheds



Although it drains a forested catchment, Kyles Creek was not considered a reference stream, since there was a small apple orchard at the monitoring site and a tomato farm less than a mile upstream. In March 2001, Kyles Creek hosted a very high number of EPT taxa (37) typical of high quality mountain streams. In October 2001, it had only 17 EPT taxa. Two natural factors likely influence this taxa loss, including (1) a number of spring EPT taxa were present in March that would not be expected in October, and (2) heavy rain events occurred one week previously that could have scoured invertebrates from the stream bed. Laurel Fork was also sampled in October 2001 after the heavy rains, and fewer EPT taxa (n=21) were collected than during the previous October. However, the community at Laurel Fork was still more diverse and intolerant of pollution. The lack of channel roughness (normally provided by channel sinuousity, large woody debris, and woody root masses from riparian shrubs and trees) may have magnified the impacts of the rain event in Kyles Creek, since roughness is needed to catch and hold microhabitat (sticks and leafpacks) and invertebrates.

A number of impacts other than toxicity likely influence the benthic community at some sites. Benthic community analysis for Clear Creek at Mills Gap Rd. and both sites on Devils Fork showed signs of organic enrichment. Habitat notes indicate excessive algal growth, a sign of high nutrients, at the upper Clear Creek site.

Habitat quality varied at the benthic sites, but most sites had riffles with coarser substrate (cobble, gravel), a decent amount of in-stream structure (score of $\geq$ 10 out of 20), and low to moderate riffle embeddedness (average score of $\geq$ 8 out of 15). Sites with the worst habitat were Clear Creek at N. Clear Creek Rd., which had a total habitat score of 45 out of 100, high embeddedness (6), and less in-stream structure (9), and Devils Fork at US 64, which had a total habitat score of 17 out of 100, limited in-stream structure (7), high embeddedness (3), and 100% sand substrate. At other study sites, although habitat was not excellent, it was still adequate to provide enough structure and food for an unimpaired benthic community.

5.3.2 Fish Monitoring

Fish were monitored at three mainstem sites on Clear Creek in October 2001, and while all sites showed some degree of impact, the site at Mills Gap Rd. was the most severely impacted, rated Fair (Tracy, 2001) (Table 5.3). Clear Creek as a whole was characterized by high levels of fish abundance and percentages of tolerant fish, moderate percentages of omnivores plus herbivores, and low diversity of intolerant species and rockbass, smallmouth bass, and trout species. Community analysis indicated problems with nutrient enrichment and habitat alteration throughout Clear Creek; the decrease in biological integrity at Mills Gap Rd. was likely a response to even higher levels of nutrient enrichment at that site.

A small and reproducing population of rainbow trout was found at the uppermost site in Clear Creek (Bearwallow Rd.). No trout were collected at any downstream sites.

Alternatively, the fish community sampled in 2002 at the benthic reference site on Crab Creek was rated Good, with a relatively low percentage of omnivores plus herbivores and a higher diversity of intolerant species and rockbass, smallmouth bass, and trout species (NCDWQ, in review).

Table 5.3 Fish Community Ratings of Clear Creek and Crab Creek

Site	NCIBI Class
Clear Creek at Bearwallow Rd. (MUCC37)	Good-Fair
Clear Creek at Mills Gap Rd. (MUCC48)	Fair
Clear Creek at Nix Rd. (MUCC19)	Good-Fair
Crab Creek at Island Cove Rd. (CRCR02)	Good

5.4 Characterization of Chemical and Toxicological Conditions

5.4.1 General Water Quality Characterization

Nutrients, specific conductance, and ions were generally higher in Devils Fork (Table 5.4) than in Clear Creek (Table 5.5). Specific conductance values at the integrator sites on Clear Creek (45 to 66 µS/cm) and Devils Fork (64 to 89 uS/cm) were high compared to that of forested mountain streams (Caldwell, 1992). Fecal coliform bacteria levels were below the NC standard of 200 colonies/100 mL; the geometric mean of 5 samples collected over 30 days was 148 and 109 colonies/100 mL for Clear Creek and Devils Fork, respectively. Dissolved oxygen levels were adequate for aquatic life, but nutrient levels were high compared to forested mountain streams (Simmons and Heath, 1982). Although total phosphorus measured five times in Clear Creek by DWQ in 2001 had a median below the detection limit of 0.02 mg/L, monthly VWIN data (orthophosphate as P) reveal higher levels for 2000 and 2001; the median phosphorus level at the middle and lower VWIN sites was 0.04 mg/L (Table B.12, Appendix B). In Devils Fork, baseflow total phosphorus measured by DWQ had a median of 0.05 mg/L, which was similar to VWIN's phosphorus (in orthophosphate) median of 0.06 mg/L. Baseflow total nitrogen measured by DWQ in both streams was high, with medians of 1.7 and 1.8 mg/L for Clear Creek and Devils Fork, respectively, which are higher than that expected for unpolluted streams in the mountains (Simmons and Heath, 1982).

Table 5.4 Water Quality Results for Devils Fork at 7th Ave. (MUDF03)

PARAMETER	BASEFLOW					STORMFLOW				
	N	MAX	MIN	MED	MEAN	N	MAX	MIN	MED	MEAN
Nutrients (mg/L)										
Ammonia Nitrogen	5	0.6	<0.1	0.1	0.2	2	1.1	1	1.05	1.05
Total Kjeldahl Nitrogen	5	1.3	0.1	0.8	0.8	2	2.7	<0.1	1.4	1.4
Nitrate+Nitrite Nitrogen	5	1.14	0.66	0.80	0.85	2	0.81	0.41	0.61	0.61
Total Nitrogen	5	2.1	0.8	1.8	1.6	2	3.1	0.9	2.0	2.0
Total Phosphorus	5	0.30	<0.02	0.05	0.09	2	0.26	0.04	0.15	0.15
Other Conventional										
DO (mg/L)	6	11.0	7.6	9.1	9.2	3	10.9	6.1	6.3	7.8
pH (Standard Units)	6	7.5	6.9	7.0	7.1	3	7.2	6.3	6.4	6.6
Specific Cond (µS/cm)	6	89	64	86	83	3	350	90	92	177
Hardness, total (mg/L)	5	29.0	24.0	25.0	25.4	1			24	
Total Suspended Solids (mg/L)	5	4.0	2.6	3.5	3.3	1			2.1	
Total Dissolved Solids (mg/L)	5	75	62	67	68	1			73	
Turbidity (NTU)	4	8.4	3.1	5.3	5.5	0				
Calcium (mg/L)	6	7.09	5.18	6.70	6.46	2	6.36	5.05	5.71	5.71
Magnesium (mg/L)	6	1.88	1.47	1.79	1.75	2	1.66	1.63	1.65	1.65
Fecal Coliform Bacteria (col/100 mL)	5	150	56	130	109[1]					

[1] Mean value for fecal coliform bacteria is the geometric mean.

Table 5.5 Water Quality Results for Clear Creek at Clear Creek Rd. (MUCC04)

PARAMETER	BASEFLOW					STORMFLOW	
	N	MAX	MIN	MED	MEAN	N	VALUE
Nutrients (mg/L)							
Ammonia Nitrogen	5	1.6	<0.1	0.1	0.4	1	0.3
Total Kjeldahl Nitrogen	5	1.1	0.1	0.7	0.7	1	<0.1
Nitrate+Nitrite Nitrogen	5	1.27	0.71	0.74	0.89	1	1.20
Total Nitrogen	5	2.3	0.8	1.7	1.6	1	1.3
Total Phosphorus	5	0.04	<0.02	<0.02	0.02	1	0.04
Other Conventional							
DO (mg/L)	6	11.5	7.6	9.0	9.1	1	9.7
pH (Standard Units)	6	7.7	6.8	6.9	7.0	1	7.6
Specific Cond (µS/cm)	6	66	45	64	60	1	65
Hardness, total (mg/L)	5	32.0	17.5	21.0	22.0	1	23.0
Total Suspended Solids (mg/L)	5	11.0	3.2	6.3	6.1	1	3.4
Total Dissolved Solids (mg/L)	5	62	54	56	56	1	58
Turbidity (NTU)	4	7.7	3.5	5.5	5.5	0	
Calcium (mg/L)	6	5.03	4.34	4.79	4.77	1	5.08
Magnesium (mg/L)	6	1.36	1.13	1.30	1.28	1	1.19
Fecal Coliform Bacteria (colonies/100 mL)	5	210	50	200	148[1]		

[1] Mean value for fecal coliform bacteria is the geometric mean.

5.4.2 Stressor and Source Identification: Pesticides and Other Organic Contaminants

Sampling of bed sediments and water provided evidence of pesticide contamination in the Clear Creek subwatershed. Pesticides were found in the water column at concentrations above ecological effects levels. Sediment toxicity was found in Clear Creek.

Pesticides were measured in water samples from baseflows and/or stormflows at a number of locations on Devils Fork, Clear Creek, and a tributary to Clear Creek—Lewis Creek. Acute toxicity bioassays were performed on most stormflow samples, and there was one failure in Devils Fork (Table B.9, Appendix B).

<u>Clear Creek</u>
To evaluate the potential for baseflow contamination, pesticides were sampled in two situations:

- Lewis Creek (MCLU28) was sampled on two dates below intensive apple pesticide spraying in order to determine if spray drift (aerial drift of pesticides from orchard to stream during pesticide application) is a delivery mechanism. It is unknown what was sprayed at the time of sampling, and no pesticides were detected. Acute toxicity bioassays were performed on these samples, and toxicity was not found.
- General characterization of baseflow at the integrator location on Clear Creek (MUCC04) was performed on one date, and no pesticides were detected.

During the growing season (March to October), storm samples were collected in Clear Creek and Lewis Creek and analyzed for acute toxicity and pesticides using varied techniques. Significant acute toxicity (mortality) was not found in any sample. Pesticides were detected in two of four storm events sampled in Clear Creek and three of five storm events sampled in Lewis Creek (Table 5.6). In June 2001, the herbicide metolachlor was measured in Lewis Creek on two dates at 1.2 and 1.4 µg/L. There are no published fresh water ecological screening benchmarks for metolachlor, but concentrations observed in Lewis Creek are several orders of magnitude below effects levels reported in the literature (see discussion in Appendix B) and acute toxicity bioassays revealed no toxicity.

In June, July, and August 2001, esfenvalerate was found in samples from three storms collected in Lewis Creek (MULC28; Table B.30 in Appendix B) and two storms in Clear Creek (MUCC19; Table B.28 in Appendix B), with concentrations ranging from 0.038 µg/L in Lewis Creek to 0.22 µg/L in Clear Creek at Nix Rd. These levels are well above those determined by Schulz and Liess (2000) to cause significant ecological effects in a caddisfly from short-term (1 hour) exposure; ecological effects levels determined by Schulz and Liess range from 0.1 to 0.0001 µg/L of fenvalerate or 0.00003 to 0.03 µg/L of esfenvalerate. Other published benchmarks for esfenvalerate were also exceeded, including those reported by the European Commission Directorate of General Health and Consumer Protection (2000) and Anderson (1982). See Appendix B for a discussion of esfenvalerate benchmarks. Since toxicity bioassays performed on these samples demonstrated no significant acute toxicity, the esfenvalerate levels found in Lewis Creek and Clear Creek were not high enough to cause mortality in the bioassay test organism *Ceriodaphnia*; however, concentrations were high enough to cause sub-lethal impacts to aquatic macroinvertebrates, assuming the esfenvalerate was in a bioavailable form. Bioavailability was not assessed during the study. Esfenvalerate has a strong affinity for sediments, however, and some or all of it may have been bound to sediments in the sample and not as available to stream organisms.

Table 5.6 Pesticides Detected in Stormflow Water Samples in the Clear Creek Subwatershed (µg/L)

Site[1] **Date**	MULC28 06/13/01	MULC28 06/22/01	MUCC19 07/18/01	MUCC19 08/03/01	MULC28 08/11/01	MULC28 08/11/01
metolachlor	**1.45**	**1.17**	-	-	-	-
esfenvalerate	**0.094**	**0.038**	**0.22**	**0.068**	**0.091**	**0.072**

[1] MULC28 = Lewis Creek at Pilot Mountain Rd., MUCC19 = Clear Creek at Nix Rd.

Sediment from Clear Creek at Mills Gap Rd. tested positive for chronic toxicity using *Hyallela azteca*, with growth and reproduction significantly reduced ($p<0.05$) (see Appendix B for details). A diverse set of pesticides was found in the sediment, including organochlorine pesticides and more recently developed pesticides (Table 5.7). Among organochlorine pesticides, DDE, DDD, sum of DDTs, alpha and gamma-chlordane, dieldrin, and heptachlor were all found at levels within the conservative benchmark range, indicating that it is possible but not probable that these pesticides singly cause toxicity. Other pesticides, esfenvalerate, carbaryl, and chlorpyrifos, were detected in the sediments, but only chlorpyrifos (for which the benchmark is much higher than the measured level) has a sediment quality benchmark for comparison. Chemical analysis of sediment detected no non-pesticide organic contaminants at Mills Gap Rd. nor at the downstream Nix Rd site. Sediments from the Nix Rd. site tested negative for chronic toxicity and had lower levels of all measured pesticides.

Devils Fork

To evaluate the potential for baseflow contamination, pesticides were sampled in two situations (a total of three samples):

- Pesticide contamination (organochlorines no longer registered for sale) of groundwater wells has been documented in the eastern part of the Devils Fork subwatershed (see Section 2.5.2). Pesticides (analysis was limited, but organochlorines were included) were analyzed on samples collected from two sites (MUDF31, MUDF32) on upper Devils Fork in December 2000 to determine whether groundwater contamination of the stream was possible. No pesticides were detected.
- General characterization of baseflow at the integrator location on Devils Fork (MUDF04) was performed on one date, and no pesticides were detected.

Three stormflow samples were collected in Devils Fork and analyzed for both acute toxicity and pesticides using varied techniques. Neither significant acute toxicity nor pesticides were found in these samples. However, an acute bioassay conducted on a fourth storm sample from Devils Fork at 7th Ave. in July 2001 failed with an LC_{50} of 54%; pesticides were not analyzed for this sample, but extremely high metal levels exceeding toxicity benchmark values were measured (see Section 5.43).

Because lower Devils Fork drains a commercial area, non-pesticide organic contaminants were analyzed in stormflow samples collected. Two polycyclic aromatic hydrocarbons, pyrene and flouranthene, were measured in each storm sample analyzed. There are no comparative screening levels found in toxicological literature for pyrene, but flouranthene concentrations (ranging from 2.5 to 15.9 µg/L) were less than the NAWQC acute benchmark of 33.6 µg/L.

Table 5.7 Pesticides Detected and Selected Metals in the Depositional Sediment of Clear Creek at Mills Gap Rd. (MUCC48), Clear Creek at Nix Rd. (MUCC19), and a Reference Stream, South Mills River (MRSM01)[1]

Contaminant	Sample Site			Benchmark Reference[2]		
	MUCC19	MUCC48	MRSM01	EPA Region 4	Conservative	Non-Conservative
ORGANOCHLORINE PESTICIDES (ppb) (Dry Weight)						
alpha-chlordane[3]	0.35	**0.77**	bdl	0.5	0.5 to 7	4.79 to 104.4
gamma-chlordane[3]	**0.67**	**2.31**	**0.74**	0.5	0.5 to 7	4.79 to 104.4
dieldrin	bdl	**0.62**	bdl	0.02	0.02 to 3.3	4.3 to 1583.4
4,4'-DDD	0.17	**1.12**	0.26	1.2	0.5 to 7	4.79 to 104.4
4,4'-DDE	0.79	**2.5**	0.91	2.07	1.42 to 5	6.75 to 374
4,4'-DDT	bdl	0.31	bdl	1.19	1.19	4.77 to 87
sum of DDTs	0.96	**3.93**	1.17	1.58	1.58 to 7	46.1 to 4450
heptachlor	bdl	**0.35**	bdl		0.3	17.4
hexachlorobenzene	bdl	2.82	bdl		10	6 to 417.6
trans-nonachlor	0.40	1.40	bdl			
OTHER PESTICIDES (ppb) (Dry Weight)						
carbaryl	1.40	7.50	NA			
chlorpyrifos	3.60	5.10	NA		92.22[4]	
esfenvalerate	23.00	7.20	NA			
METALS (ppm) (Dry Weight)						
beryllium	1.14	bdl	bdl			
cadmium	**1.18**	**0.934**	**0.596**	0.676	0.583 to 1.2	3 to 41.1

1 Values in bold are greater or equal to at least one benchmark. Bdl = below detection limit. MUCC19 and MUCC48 sampled on 7/16/01 and MRSM01 sampled on 8/10/01. NA = not analyzed.
2 Where appropriate, non-conservative benchmarks were adjusted for the lowest total organic carbon value for Clear Creek—1.74% (the TOC for MUCC48).
3 Benchmark values are for chlordane.
4 Value is the chronic sediment benchmark from New York State Department of Environmental Conservation, adjusted for 1.74% TOC.

5.4.3 Stressor and Source Identification: Metals

Selected total metals concentrations measured in the watershed were compared to the chronic and acute EPA NAWQC and Tier II criteria (screening values) that were adjusted for mean hardness (Table 5.8; Table B.12, Appendix B for VWIN data).

<u>Clear Creek</u>
In lower Clear Creek, in one of two storms sampled, copper, lead, and zinc levels exceeded EPA's acute benchmarks; however, this sample passed an acute toxicity bioassay. Only one storm sample was analyzed for metals from Lewis Creek, and cadmium, copper, lead, and zinc levels exceeded EPA's acute benchmarks; this sample also passed an acute toxicity bioassay. DWQ baseflow medians for all metals are below screening levels, with 1 of 6 samples above the chronic benchmark for zinc and lead. In addition, although median baseflow concentrations for

copper, lead, and zinc were below chronic benchmarks, a percent of VWIN samples taken in lower Clear Creek at Nix Rd. exceed the chronic benchmarks for copper (18%), lead (4%), and zinc (14%). The VWIN data show an increase in median concentrations for copper, lead, and zinc from middle (Apple Valley Rd.) to lower Clear Creek (Nix Rd.).

North Carolina has standards or action levels for the protection of aquatic life for some metals. In general, these values are higher than chronic and acute EPA criteria adjusted for hardness. In Clear Creek, baseflow metal medians were below all standards and action levels, and one sample exceeded the NC benchmark for silver. The one Clear Creek stormflow sample analyzed had concentrations of copper, iron, lead, and zinc above DWQ action levels or standards. The Lewis creek stormflow sample exceeded the DWQ benchmarks for cadmium, copper, lead, and zinc. VWIN samples were all below DWQ benchmarks except one sample in lower Clear Creek, which exceeded the action level for copper.

Reference data from the French Broad River at Rosman (see Section 4.4.3 for discussion) (DWQ station number 03439000) provide a comparison for certain metals. Median copper and zinc in the French Broad River are higher than both DWQ and VWIN median baseflow concentrations for Clear Creek.

Table 5.8 Selected Metals in Clear Creek and Devils Fork and Comparison Values of the French Broad River at Rosman and EPA Screening Levels [1,2,3]

Site	Total metal concentration (µg/L)					
	Cadmium	Copper	Lead	Silver	Zinc	Calculated Hardness (mg/L) [4]
NCDWQ Class C Standard	**2.0**	**7**	**25**	**0.06**	**50**	
Clear Creek at Nix Rd. (MUCC19)						
7/19/2001--stormflow	<0.1	**13**	**27**	<0.5	**92.3**	19.3
Adjusted acute benchmark	0.7	3	10	0.2	29.7	
Clear Creek at Clear Creek Rd. (MUCC04)						
3/12/2001--stormflow	<0.1	1	<1	<0.5	1.7	17.6
Adjusted acute benchmark	0.6	3	9	0.2	27.5	
Baseflow median (n=6)	0.1	1	1	**0.5**	2.3	17.3
Adjusted chronic benchmark	0.6	2	0.3	0.4	27.1	
Lewis Creek at Pilot Mtn Rd. (MULC28)						
8/11/2001--stormflow	**3.3**	**15**	**42**	<0.5	**106.3**	19.3
Adjusted acute benchmark	0.7	3	10	0.2	30.0	
Devils Fork at 7th Ave. (MUDF03)						
Stormflow median (n=4)	0.2	**6**	**10**	<0.5	**86.5**	19.3
Adjusted acute benchmark	0.7	3	10	0.2	29.7	
Baseflow median (n=6)	0.1	<1	<1	<0.5	4.1	24.1
Adjusted chronic benchmark	0.8	3	0.5	0.4	35.9	
French Broad River at Rosman: median of 53 samples collected between 1/93 and 12/ 97		**3**			16.0	

[1] Baseflow values and French Broad River medians ≥ the chronic benchmark and stormflow values ≥ the acute benchmark are in bold type. If the value was < the DL, it is listed as "<DL".
[2] Chronic and acute benchmarks for all metals except Ag are EPA NAWQC values. Those for Ag are EPA Tier II Values. Benchmarks were adjusted for site-specific hardness.
[3] Metals listed are those with at least one sample from the Mud Creek watershed above the screening level.
[4] Hardness calculation = ([Ca^{2+}] X 2.497) + ([Mg^{2+}] X 4.118). Data not available for French Broad River.

All metals in Clear Creek sediments were below screening benchmarks except cadmium, which was found at levels above conservative benchmarks (Table 5.7) and approximately twice the concentration found in reference sediment from the South Mills River. Beryllium was measured in these sediments, as well, but there are no published screening benchmarks for this metal.

Devils Fork

In lower Devils Fork, DWQ stormflow medians are at or above benchmark levels for copper, lead, and zinc. **The one (of four) storm sample (7/19/2001) that failed an acute toxicity bioassay (LC_{50} of 54%) had the highest lead (77 µg/L), copper (17 µg/L), and zinc (581 µg/L) concentrations measured during the study.** These concentrations are 6 to 20 times respective acute benchmark levels. DWQ median baseflow concentrations of all metals are below screening levels, with 1 of 6 samples exceeding chronic benchmarks for cadmium and lead. VWIN data also show higher metals levels for lower Devils Fork, with 54% and 14% of samples exceeding the benchmarks for copper and lead, respectively.

In Devils Fork, DWQ baseflow metal medians were below all North Carolina standards and action levels; however, 1 of 6 baseflow samples had concentrations above the iron or lead benchmarks. In stormflow samples, 1 of 4 had copper, iron, and lead above DWQ benchmarks and 3 of 4 had zinc levels above the DWQ benchmark. VWIN samples were all below DWQ benchmarks.

Comparison to reference data from the French Broad River at Rosman (see Section 4.4.3 for discussion) demonstrates that median copper and zinc in the French Broad River at Rosman are higher than both DWQ and VWIN median baseflow concentrations for Devils Fork.

5.4.4 Stressor and Source Identification: Suspended Sediment

Median suspended sediment concentrations (SSC) measured during storms at the furthest downstream monitoring sites on Clear Creek and Devils Fork were 304 and 137 mg/L, respectively (see Section 2.2, Appendix B).

5.5 Channel and Riparian Area Summary

Brief examinations of stream and riparian conditions were performed for Clear Creek and Devils Fork and their tributaries. Sections of the Clear Creek mainstem have been channelized (26% according to IPSI estimates), but it has considerably more sinuousity than much of Mud Creek. Along much of its length, it is bordered by a thin forested riparian area, often just a single line of mature trees. This woody vegetation provides some bank stability and edge habitat (undercut banks), as well as organic microhabitat (Figure 5.3). There are frequent areas of bare and unstable banks along Clear Creek, especially where there is no woody vegetation, cattle have had access to the stream, or bridges have altered the flow pattern of the creek (Figure 5.4). Sand and silt does build up in slower sections of the creek, but Clear Creek's moderate gradient pushes much of these fine sediments through faster riffle and run areas. An active sand dredging business operates near the mouth of the creek.

Figure 5.3 Clear Creek with woody riparian vegetation.

Figure 5.4 Clear Creek in old pasture.

Tributaries of Clear Creek vary in their channel and riparian area characteristics. Generally, tributaries that flow off the northern ridge (e.g., Laurel Fork) have good in-stream habitat, with an adequate mix of inorganic substrate. Where woody riparian vegetation is present, organic microhabitats (woody debris, leafpacks) are abundant (Figure 5.5). Tributaries that flow from the southeast, such as Lewis Creek, are lower gradient and flow through agricultural or residential land. These streams have often been channelized and have little woody riparian vegetation; many of them are incised and unstable. They are unable to transport finer sediments, and sand and silt comprise most of the bed substrate.

Figure 5.5 Laurel Fork.

Figure 5.6 Devils Fork at US 64.

Devils Fork and its tributaries drain an agricultural and residential catchment, and accordingly, woody riparian vegetation is limited and large sections of the streams have been channelized. The IPSI identified 44% of stream miles in the subwatershed as channelized (TVA, 2001). The downstream section of Devils Fork (~2 miles) is extensively channelized, the stream channel very straight and deep (Figure 5.6). Streams in this subwatershed are generally sandy.

5.6 Conclusions: Identification of Causes and Sources of Impairment

Based on benthic data collected during this study, most of Clear Creek is impaired, although there has been some recovery in the upper part of the creek at Bearwallow Rd. No biological or chemical data had been collected on Devils Fork prior to this study, and it had not been rated. Data collected during this study indicate that it is severely impacted, but it is too small to rate using benthic community data. *Although it has not been officially rated as impaired, this report addresses stressors in Devils Fork with the same language that is used for officially impaired streams (e.g., "causes of impairment").* Tributaries to Clear Creek that were sampled are not separately addressed with this language, but data from them will be used in discussions on causes and sources of impairment for Clear Creek and Devils Fork. Each stressor investigated during this study is evaluated below. See Section 3.5.1 for definitions of stressor types (e.g., cumulative cause of impairment).

5.6.1 Pesticides

> Exposure to toxicants is a primary cause of impairment for Clear Creek and Devils Fork. Pesticides are the most likely toxicants for these streams.

Benthic community analysis provides evidence of toxic impacts to Clear Creek, Devils Fork, and Clear Creek tributaries, Mill Creek and lower Cox Creek. The benthic communities in these streams demonstrated typical characteristics of toxic stress: toxicant-intolerant taxa, such as stoneflies, were typically absent, and tolerant taxa were dominant. In addition, in Clear Creek at Mills Gap Rd. had two additional toxicity indicators: 1) *Chironomus* mouthpart deformity analysis indicated severe toxicity; and 2) sediments failed chronic toxicity tests, causing depressed growth and reproduction in test organisms.

Benthic sampling during the present study expanded on previous monitoring by DWQ that indicated severely stressed benthic communities in streams that drain considerable area of apple orchards. Land use, biological, chemical, and toxicological data from the present study provides further evidence that streams draining apple orchards are exposed to toxicants.

However, there are considerable areas of row crops in both the Clear Creek and Devils Fork subwatersheds. As noted in Section 4.6.1, tomato/pepper pesticides may cause toxic impacts in upper Mud Creek. It is not possible to differentiate between tomato/pepper fields and other row crops with the land use information provided by TVA’s Integrated Pollutant Source Identification for the Clear Creek and Devils Fork subwatersheds, although much of the row crop acreage in the Clear Creek subwatershed is planted in corn. The Devils Fork subwatershed has a similar area in row crops (9% of total area according to the IPSI) and in apple orchards (13% of the total area) spread throughout the drainage area, and it is not possible to distinguish between pesticide impacts from apple orchards and row crops for this subwatershed. In the upper Clear Creek subwatershed, the bulk of cropland is planted in apples and there are few row crops. The potential for pesticide impacts from row crops in Clear Creek is greatest in the lower half of the subwatershed, primarily below Mills Gap Rd.

Reference streams with similar habitat and watershed size (Laurel Fork, Harper Creek) to study streams but no apple orchards or row crops were characterized by benthic communities with much higher EPT richness and lower biotic index scores. Crab Creek, a reference stream for Clear Creek with a watershed that has no apple orchards but does have row crops, was characterized by a Good benthic community (vs. Fair or Poor communities in Clear Creek). Cox Creek was sampled above and below apple orchards and a small area (<2 acres) of row crops, and although habitat was similar, lower Cox Creek had fewer EPT taxa, two or fewer of the seven stonefly taxa seen in upper Cox Creek, and a much more pollution-tolerant benthic community.

Chemical analysis of sediments provides evidence of pesticide inputs to Clear Creek. A number of organochlorine pesticides no longer registered for sale (widely used in the past, and some previously used on row crops and orchards), including DDT, DDD and DDE (DDT breakdown products), chlordane, heptachlor, hexachlorobenzene, and dieldrin, were present. Some of these pesticides were detected at levels above conservative screening benchmarks (below which there is low probability of toxicity), but not above non-conservative benchmarks (above which there is high probability of toxicity); thus, it is possible but not probable that these contaminants can singly cause toxicity (see Section 3.3.1 for discussion of sediment benchmarks). Carbaryl, esfenvalerate, and chlorpyrifos, three currently used insecticides, were measured, as well. Carbaryl (trade name Sevin®) and esfenvalerate (tradename Asana®) are applied by apple growers in the spring and are used on row crops such as tomatoes and/or corn. The organophosphate chlorpyrifos (trade name Lorsban®) is still used by some apple growers, although its popularity has declined (Jim Walgenbach, NC Cooperative Extension Service, personal communication). Chlorpyrifos is also used on lawns, row crops, and to treat livestock.

Sediment pesticides were measured at higher levels in the middle portion of Clear Creek (Mills Gap Rd.) than in lower Clear Creek (Nix Rd.), and sediment toxicity was only observed at Mills Gap Rd. A number of pesticides no longer registered for sale were present at levels above conservative benchmarks, which indicates that it is possible but not probable that these pesticides singly cause toxicity. Sediment benchmarks only address the singular impacts of contaminants; comparison of contaminant levels to benchmarks does not address cumulative toxicological effects of multiple contaminants. It is also possible that there were pesticides and pesticide breakdown products in the sediments that could not be analyzed; for example, laboratory analysis was not available for 35% of commonly used apple pesticides (Table B.51, Appendix B). No other contaminants other than cadmium were detected in these sediments, and it is unlikely that cadmium is problematic at the measured concentration. The US Forest Service found similar cadmium levels in sediments in another NC mountain stream, Scotsmans Creek, which has a largely forested watershed and hosts a healthy aquatic invertebrate community (Richard Burns, US Forest Service, personal communication). Therefore, it is most probable that additive effects of pesticides (analyzed and unanalyzed) caused sediment toxicity in middle Clear Creek.

Limited storm sampling documented inputs of esfenvalerate at levels well above those that can impact the lifecycles of aquatic insects after short-term exposure (see Section 5.4.2). The bioavailability of esfenvalerate in these samples is unknown, and some or all of it may have been bound to sediments in the samples (see Section 5.4.2). These esfenvalerate levels were found in lower Clear Creek, below large areas of both row crops and apple orchards, which are both potential sources of this pesticide. High esfenvalerate levels were also found in upper Lewis

Creek, which drains a large apple growing area (approximately 670 acres) and a small area of row crops (approximately 45 acres). Pesticides in stormflows likely come from orchard or field runoff; orchard runoff has been noted as a key mechanism for pesticide delivery to streams in other studies (e.g., Schulz, 2001; Giroux, 1998). Storm sampling conducted during the study was limited to a few events (four storms in Clear Creek, five storms in Lewis Creek and two in Devils Fork) sampled over a single growing season. It is likely that storms not sampled also carried pesticides, perhaps at levels that impact macroinvertebrate communities.

Although limited sampling of the water column only found pesticides in stormflows, other delivery mechanisms are possible. Poor pesticide handling (e.g., spills, lack of functioning backflow preventors) can also result in pesticide contamination of surface waters. Schulz et al. (2001) found that pesticide contamination of streams from orchard spray drift caused mortality in *Chironomus* from 24 hours of exposure. Although no pesticides were measured in the two samples taken in-stream directly below pesticide spraying (it is unknown which pesticide was used), this limited dataset does not provide definitive evidence that spray drift is not a method of delivery to study streams. It is also possible that analytical methods were not available for the pesticide used.

It is unclear how accountable pesticides no longer registered for sale are in current biological impairment. Many organochlorines have a high affinity for soils and are persistent [e.g., soil half-life of DDT ranges from 2-15 years (USEPA, 1989; Augustijn-Beckers, 1994)]. These chemicals likely reach streams through erosion of contaminated upland soils. Many stream bottom areas that are now farmed in apples were farmed in row crops (e.g., cabbage and beans) in the 1950 to 1970s when pesticides were applied liberally relative to the present. DDT was also used around homes and gardens. Although popular for mosquito control, DDT was not used by Henderson County for this purpose (Henderson County Health Department, personsal communication).

In upper Clear Creek at Bearwallow Rd., an improvement in benthic community health (from Fair to Good-Fair) was observed since 1993, when the stream was previously sampled. This may be due to several factors, including the loss of apple orchards in the area and proximity of the upstream tributary of Laurel Fork, which likely serves as a high quality colonization source for benthic invertebrates through drift. Downstream drift is a key mechanism for aquatic invertebrate community maintenance (Waters, 1972; Williams and Hynes, 1976). If drift sources are present, recolonization from a catastrophic event (such as scouring stormflows or toxicants) can occur quickly; recovery from floods in a small stream in Missouri occurred within one month (Ryck, 1975).

There are nine wastewater treatment plants (WWTPs) in the Clear Creek and Devils Fork subwatersheds, and they are a potential source of toxicants (e.g., chlorine, ammonia). Although WWTPs were not intensively investigated as sources of toxicants, it is generally unlikely that they play a major role in biological impairment due to their physical locations and compliance records. Some streams with benthic communities typical of toxic stress (Cox Creek, Mill Creek, upper Devils Fork) had no WWTPs on them at all. Only two facilities in the Clear Creek subwatershed were non-compliant for one month in 2000-2001 (Camp Judea on Henderson Creek and Greystone Subdivision on Clear Creek) due to missing parameters; no other problems were noted for WWTPs in the subwatershed. In the Devils Fork subwatershed, Dana Hill Corporation (on a tributary to Devils Fork) violated the ammonia limit four times in 2001;

ammonia may indeed impact the tributary and less likely, lower Devils Fork, but the benthic community in lower Devils Fork was sampled in 2000 before these violations.

High levels of metals were also noted in this watershed, and these may also play a role in biological impairment, especially in lower Devils Fork. See Section 5.6.2 for discussion.

Analysis of benthic macroinvertebrate data indicates widespread toxic impacts on benthic organisms in Clear Creek and Devils Fork. *Exposure to toxicants is considered a primary cause of impairment in these subwatersheds. Given the pattern of biological impairment and the location of potential source areas, pesticides from apple orchards and/or row crops are the most likely toxicants. The specific pesticides contributing to toxic impacts (including the roles of past use pesticides vs. pesticides in current use) cannot be determined with the available data. Similarly, the relative contribution of row crops and apple orchards cannot be clearly differentiated.*

5.6.2 Habitat Degradation Due to Sedimentation

Sedimentation is a cumulative cause of impairment for lower Devils Fork and a contributing stressor for Clear Creek and upper Devils Fork.

Most sites on Clear Creek and Devils Fork exhibited some degree of excess sediment deposition, but it was severe only in lower Devils Fork (at US 64). Here, sand and silt comprised 100% of the bottom substrate and riffles were non-existent. This is not solely due to the magnitude of sediment load, but also due to the stream's lack of ability to transport fine sediment through its low gradient, straight channel. Upper Devils Fork (at Howard Gap Rd.) and lower Clear Creek (at Nix Rd.) did have considerable amounts of silt and sand, but riffles of moderate quality were still present. *Sedimentation is considered a cumulative cause of impairment for lower Devils Fork. It is a contributing stressor for Clear Creek and upper Devils Fork.*

Sediment sources. Sources of sediment are numerous and come from both in-stream and upland sources. Unstable and unvegetated banks on Clear Creek, Devils Fork, and their tributaries are important sources of sediment. Various sections of the creeks have been channelized, which is often accompanied by incision. The practice of clearing bank vegetation further destabilizes stream banks. Exposed loose soil erodes into streams during storm events, increasing suspended and bed load sediments.

Upland sources of sediments are important in this watershed as well. Residential and commercial site development, road construction, established home sites with eroding slopes, unpaved roads and driveways, and eroding road banks provide sources of sediment.

5.6.3 Habitat Degradation--Other Issues

Lack of organic microhabitat and a diversity of depth and velocity combinations (riffles, pools, bends), are considered cumulative causes of impairment for lower Devils Fork.

Lower Devils Fork (defined as the lower two miles) has been channelized, and the channel is an extremely straight and wide ditch with virtually no riffles, pools, or bends. As described in Section 4.6.2, a diversity of depth and velocity types within a stream channel not only serve as key habitats themselves but also are important in catching organic microhabitats, such as sticks and leaves.

Limited riparian vegetation was also an issue for lower Devils Fork. Vegetation was often limited to a thin fringe of invasive shrubs. This vegetation does provide a source of sticks and leafpacks important for benthic macroinvertebrates. However, undercut banks and large woody debris provided by trees were limited. Undercut banks and large wood not only provide habitat and a food source for aquatic organisms, but they also contribute to channel roughness, or irregularity, catching smaller organic microhabitats.

These habitat issues likely act in concert with sedimentation to impact the aquatic community in lower Devils Fork. *Lack of suitable in-stream habitat, including organic microhabitat and a diversity of depth and velocity combinations (riffles, pools, bends), is considered a cumulative cause of impairment for lower Devils Fork.*

5.6.4 Metals and Petroleum Pollutants

Urban pollutants from stormwater runoff are a primary cause of impairment for lower Devils Fork. Metals are a potential cause or contributor to impairment for Clear Creek.

Metals in Devils Fork and Clear Creek were occasionally above water quality benchmarks. Baseflow metal concentrations in Clear Creek and Devils Fork were generally below benchmarks. Limited stormflow sampling in lower Clear Creek (1 of 2 samples collected) and Lewis Creek (1 of 1 sample collected) demonstrated high levels of cadmium, copper, lead, and/or zinc, but acute toxicity bioassays performed on the samples did not indicate toxicity. It is likely that these high metal concentrations were not bioavailable, perhaps bound to particulate matter. It is unclear how representative of stormflow conditions these two samples are; if these stormflow metal concentrations are typical, it is possible that these levels play a role in cumulative sub-lethal effects to the biological community over time. Even if metals play a role in biological impairment, it is clear that it is not the only toxicant based on detections of esfenvalerate in water and current and past use pesticides in sediments.

Sources of these metals are unknown. Metal roofs and pipes can serve as sources of zinc and perhaps cadmium. High metal levels have been found in stormwater draining old agricultural sites in other areas; it has been hypothesized that residues of old pesticides containing metals are sources in these areas (Bales et al., 1999). It is also possible that there are natural sources of some of these metals; mineralization of watershed rock can provide concentrated sources of some metals.

A storm sample from lower Devils Fork did have extremely high levels of copper, lead, and zinc that are 6 to 20 times the acute benchmarks. This sample failed an acute toxicity bioassay, and it is likely that the high metal levels were responsible for the observed toxicity. Organic contaminants analyzed for this sample were below published screening benchmarks.

Lower Devils Fork drains a significant portion of commercial land along US 64/Four Seasons Boulevard. The 7th Ave. sampling location marks the confluence of Devils Fork with a tributary that drains much of this commercial land. At the time of sampling, the tributary was contributing a majority of the flow in Devils Fork. Runoff from the parking lots, streets, and roofs in this commercial area is the most likely source of these metals.

The limited amount of stormflow sampling did not provide any evidence that pollutants other than metals were at problematic levels in Devils Fork. The large diesel and gasoline spill into a Devils Fork tributary at I-26 in May 2000 (See Section 2.5.2) may be partially responsible for the severely impacted benthic community sampled in lower Devils Fork in July 2000. In addition, because lower Devils Fork drains a large area of commercial land, the potential for problematic concentrations of other urban pollutants (such as organic contaminants) is present.

As stated previously, exposure to toxicants is considered a primary cause of impairment for Devils Fork, and pesticides are the likely reason for toxicity, especially in upper Devils Fork. In addition, urban pollutants from stormwater runoff are likely toxicants for lower Devils Fork based on analysis of potential sources. It is not clear what role metals play in impairment in Clear Creek, and they are considered a potential cause or contributor to impairment.

5.6.5 Nutrients

Nutrient enrichment is a contributing stressor for Clear Creek and Devils Fork.

Benthic and fish community analysis indicated nutrient enrichment issues in Devils Fork and Clear Creek. The benthic macroinvertebrate communities of both sites on Devils Fork included taxa tolerant of organic enrichment. For Clear Creek, fish community analysis indicated issues with nutrient enrichment, which were especially pronounced at the middle (Mills Gap Rd.) site. Benthic data from Mills Gap Rd. also indicated organic enrichment, and signs of nutrient enrichment (excessive algal growth) were noted at the uppermost site (N. Clear Creek Rd.). At each of these sites, toxicity was the overwhelming factor driving benthic impairment (in lower Devils Fork, habitat degradation is also a driving factor). *However, nutrient enrichment likely serves as a low level stressor for the biological community. It is considered a contributing stressor for Clear Creek and Devils Fork.*

Nutrient sources for these creeks are numerous. Cattle access to Clear Creek, Devils Fork, and their tributaries is a chronic problem. The organic enrichment noted in Clear Creek at Mills Gap Rd. is likely due in large part to cattle access along almost a mile of Puncheon Camp Creek, a tributary that enters Clear Creek just upstream of Mills Gap Rd. Waste from straight-pipes and failing septic systems is a possible source of nutrients. Fertilizers used on crops and lawns are also possible sources.

5.6.6 Other Possible Stressors

The extended drought that began mid-1998 decreased flows in the Mud Creek watershed, and may serve as an additional stressor to aquatic invertebrate communities (see Section 4.6.4). However, it is unlikely that low flows are a key stressor; reference sites in the adjacent Crab Creek watershed sampled during the same period (see Sections 5.3 and 6.3) were rated Good or Excellent.

5.6.7 Conclusion

Clear Creek

A number of stressors impact Clear Creek, but the primary cause of impairment is exposure to toxicants. The most likely toxicants are apple orchard and row crop pesticides. Sedimentation and nutrient enrichment are contributing stressors. Metals are a potential cause or contributor to impairment.

Devils Fork

A number of stressors also impact Devils Fork, and the primary cause of impairment is exposure to toxicants. The most likely toxicants are apple orchard and row crop pesticides. For lower Devils Fork, metals from stormwater runoff are also likely toxicants. Sedimentation is a contributing stressor for upper Devils Fork; in lower Devils Fork, both sedimentation and lack of suitable in-stream habitat, including organic microhabitat and a diversity of depth and velocity combinations (riffles, pools, bends), are considered cumulative causes of impairment. Nutrient enrichment is also a contributing stressor for Devils Fork.

Section 6
Results and Conclusions: Bat Fork Subwatershed

Bat Fork drains agricultural, industrial, residential, and commercial land and is considered impaired for its entire length. Its watershed includes King Creek, which drains residential land, a golf course, and residential camps. At its downstream end, Bat Fork enters Johnson Drainage Ditch, which joins Mud Creek at the north end of Hendersonville. DWQ's Biological Assessment Unit performed a study of the benthic community of Bat Fork in 1989 and documented impacted benthic communities at five sites along the stream. These impacts were attributed to General Electric's effluent (now sent to the Hendersonville wastewater treatment plant) and contaminated groundwater (50-60% of the plume is now treated), three other point sources (two of which are no longer operating), and various non-point source pollutants. In 1997, benthic monitoring at one downstream site indicated some improvement from 1989, but the community was rated Fair.

The fish community of Bat Fork at Airport Rd. was sampled by DWQ in 1997. Bat Fork was rated Poor and had an abundance of omnivores and herbivores, no intolerant taxa, many non-native fish, and many tolerant fish; community composition was indicative of habitat degradation and excessive nutrients.

The Volunteer Water Information Network (VWIN) samples at one site on upper Bat Fork. Data collected before the onset of the present study indicated high nitrogen and conductivity levels.

6.1 Key Stressors Evaluated in the Bat Fork Subwatershed

Plausible causes of biological impairment in the Mud Creek watershed were identified using both bioassessment and watershed-driven approaches (Figure 1.2). Biological community data, habitat information, and land uses and activities were considered to flag stressors for further investigation. Based on preliminary review, the following stressors were evaluated as the most plausible candidate causes of impairment in Bat Fork for further investigation:

1. <u>Habitat degradation due to sedimentation.</u> Habitat degradation due to sedimentation manifests itself in the loss of pools, burial of riffles, and high levels of substrate instability. Excess sedimentation has been noted by field staff for Bat Fork.

2. <u>Toxicants.</u> Multiple sources of toxicants exist in the watershed, including contaminated groundwater from the General Electric Superfund site (GE) and pesticides from residential and agricultural land uses.

6.2 Monitoring Locations

Monitoring site locations as listed below were chosen in order to characterize stream integrity, identify stressors, and pinpoint sources of these stressors. Benthic invertebrate communities and water chemistry were monitored in this subwatershed primarily during the period of 2000-2001 (Figure 6.1, Table 6.1). VWIN chemical data were also used in this analysis.

Table 6.1 Summary of Monitoring Approaches Used at Primary Sampling Sites, Bat Fork Subwatershed

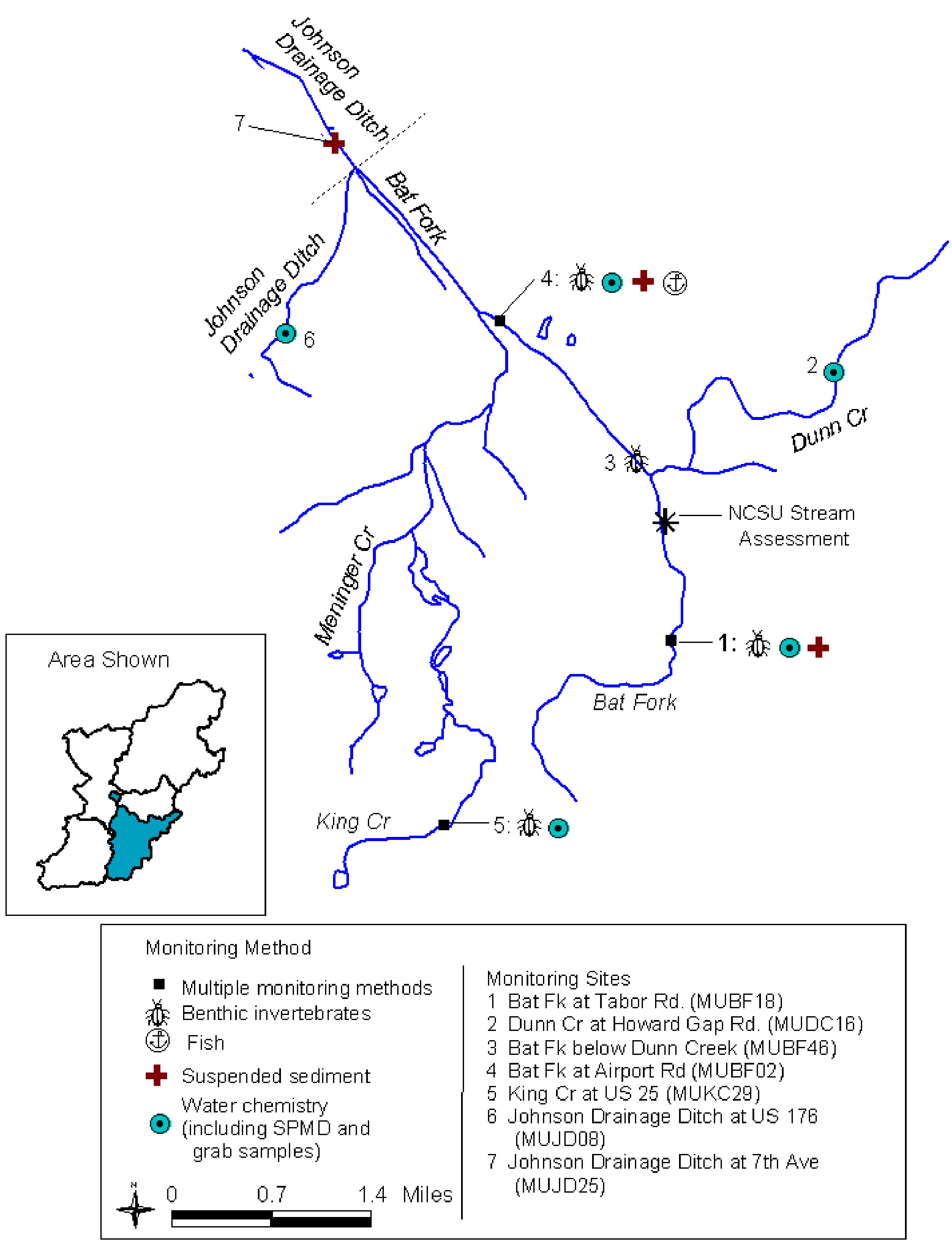
Station Code	Location	Benthos	Fish	DWQ Water Quality[1]	VWIN Water Quality[1]	Data Sonde	Suspended Sediment
Bat Fork and Johnson Drainage Ditch Mainstem							
MUBF18	Bat Fork at Tabor Rd.	✓		✓	✓	✓	✓
MUBF46	Bat Fork below Dunn Creek	✓					
MUBF02	Bat Fork at Airport Rd.	✓	✓	✓+			✓
MUJD08	Johnson Drainage Ditch at US 176			✓			
MUJD25	Johnson Drainage Ditch at 7th Ave.						✓
Bat Fork Tributaries							
MUDC16	Dunn Creek at Howard Gap Rd.			✓			
MUKC29	King Creek at US 25	✓		✓			
Reference							
CRCR03	UT to Crab Creek at Crab Creek Rd.	✓					

1 Grab samples and/or repeated field measurements.
\+ Integrator station.

Bat Fork Mainstem and Johnson Drainage Ditch (Upstream to Downstream)

- *Bat Fork at Tabor Rd (SR 1809)* (MUBF18). This location is just below GE's Superfund site and a significant stretch of stream accessed by cattle. Benthic macroinvertebrates and water chemistry were monitored here. Physical/chemical sampling focused on suspended sediment, organic contaminants, and chronic toxicity. A data sonde was used to measure specific conductance and dissolved oxygen over time. This is also a VWIN site.
- *Bat Fork below Dunn Creek* (MUBF47). This is just below the confluence of Dunn Creek, which drains a large area of apple orchards. Benthic macroinvertebrates were monitored here.
- *Bat Fork at Airport Rd. (SR 1779)* (MUBF02). This site is the lowest benthic monitoring site on Bat Fork. The fish community was monitored in 2002. It is an integrator site and was sampled for basic physical/chemical water quality parameters as well as for suspended sediment and pesticides.
- *Johnson Drainage Ditch at US 176* (MUJD08). This location is downstream of stormwater inputs from strip malls and commercial businesses on US 176 and is south of downtown Hendersonville. It is upstream of Johnson Drainage Ditch's confluence with Bat Fork. One stormflow sample was collected for metals, organics, pesticides, and acute toxicity.
- *Johnson Drainage Ditch at 7th Ave.* (MUJD25). This location is the most downstream location on Johnson Drainage Ditch, and suspended sediment was sampled here.

Figure 6.1 Monitoring Sites in the Bat Fork Subwatershed



Bat Fork Tributaries

- *Dunn Creek at Howard Gap Rd. (SR 1006)* (MUDC16). This site is downstream of orchard operations and in the vicinity of residential drinking water wells that contain organochlorine pesticides no longer registered for sale (see Section 2.5.2). A sample was taken during low baseflow levels in the winter and analyzed for pesticides.
- *King Creek at US 25* (MUKC29). This site is downstream of the Kenmure residential golf community and its wastewater treatment plant. Samples were collected for metals, MBAS, total residual chlorine, and nutrient analysis. Benthic macroinvertebrates were also monitored here.

Reference

- *Unnamed tributary to Crab Creek at Crab Creek Rd. (SR 1127)* (CRCR03). This site was a benthic reference site for Bat Fork at Tabor Rd. and King Creek. It drains a small forested watershed.

6.3 Characterization of the Biological Community and Stream Habitat

6.3.1 Description

Selected habitat and biological characteristics for each site sampled during the study are shown in Table 6.2. Some streams were too small to be given a formal rating (bioclassification). See Section 3.2.2 and Appendix A for additional details. A narrative summary of conditions at each site follows.

Bat Fork

- *Bat Fork at Tabor Rd.* This site was sampled in July 2000. Although it had some habitat problems, this site had the best habitat of all Bat Fork monitoring sites (score of 73 out of 100). Inorganic substrate was a mix of bedrock, cobble, gravel, and sand/silt, but in lower flow areas, sand and silt were predominant. In-stream organic microhabitat was present, with plenty of sticks and undercut banks but limited large woody debris and leafpacks. The biological community was impacted, but much improved from 1989, when it was last sampled. It had an EPT richness of 14 (up from 2 in 1989) and a moderate BI (5.48). **The benthic community was dominated by pollution-tolerant macroinvertebrates, but some intolerant taxa (including the only stonefly taxon found in Bat Fork) were also present.**
- *Bat Fork below Dunn Creek.* This site is within the channelized section of Bat Fork, with a thin belt of shrubby and herbaceous vegetation on its steep banks. The habitat score of this site dropped by 42 points from that at Tabor Rd. Inorganic substrate was sandier (70%), and riffles were more embedded than those of the upstream site. The only available organic microhabitat available consisted of undercut banks and root mats; sticks, large woody debris, and leafpacks were missing. **When sampled in July 2001 (one week after heavy rains), it had only 9 EPT taxa and was dominated by pollution-tolerant taxa** (BI of 6.33). Some taxa indicative of low dissolved oxygen were also present. Recent stormflows could have scoured some macroinvertebrates and smaller organic microhabitat from the site.

Table 6.2 Selected Benthic Community and Habitat Characteristics at Study Sites in the Bat Fork Subwatershed[1]

Site	Date	Substrate % sand and silt[2]	In-stream Structure Score (of 20)[3]	Embeddedness Score (of 15)[4]	Habitat Score Total (of 100)[5]	EPT Richness[6]	EPT Biotic Index[6]	Biotic Index[6]	Bioclassification[6]
Bat Fork at Tabor Rd.	4/89	70				2			Not Rated**
	7/10/00	55	12	12	73	14	5.09	5.48	Not Rated**
Bat Fork below Dunn Creek	7/23/01	70	5	5	31	9	6.12	6.33	Not Rated*
Bat Fork at Airport Rd.	4/89	90				2			Poor
	9/97	95		3	48	7	6.31	6.97	Fair
	7/10/00	95	10	3	44	9	6.06	6.94	Fair
	7/23/01	75	11	5	37	7	6.03	6.93	Not Rated*
King Creek at US 25	10/25/00	25	12	3	64	10	5.66	5.26	Not Rated**
Reference									
UT to Crab Creek at Crab Creek Rd.	10/26/00	15	16	3	72	25	2.36	3.87	Excellent

1 Limited data are available for samples from 1997 and 1989.
2 Based on visual estimate of substrate size distribution.
3 Visual quantification of the of in-stream structures present, including leafpacks and sticks, large wood, rocks, macrophytes, and undercut banks/root mats.
4 Estimation of riffle embeddedness, or the degree which a riffle's larger inorganic substrate is buried by sand and silt. The higher the score, the less embedded. Low scores of King Cr. and UT to Crab Cr. do not reflect embeddedness; bedrock was the base riffle substrate at these sites, and bedrock is given a low score for this metric due to its lack of suitability as benthic habitat for many species.
5 See Section 3.2.4 for a list of component factors.
6 See Section 3.2.4 for description. Seasonally corrected scores are presented for EPT Richness and Biotic Index.
* Sampled with Qual 5 method, which currently has no rating method.
** Sampled with Qual 4 method. Impacted, but too small to rate
.

- *Bat Fork at Airport Rd.* Like the site below Dunn Creek, this site was characterized by poor habitat (mean score of 40 out of 100). It is a very deep, wide, and straight ditch and dammed multiple times by beavers. Sand was the predominant bottom substrate (mean of 85%) and there were no riffles. Its organic microhabitat was limited to some large woody debris, undercut banks and root mats, and sticks. It was sampled in July 2000 and 2001 (just after storms), and the benthic community changed little from when it was sampled before in September 1997. Community composition was also similar to that at the site below Dunn Creek, with low EPT richness (mean of 8) and a high BI (mean of 6.94). **The dominant taxa were pollution-tolerant, and taxa indicative of low dissolved oxygen were present. It was rated Fair in 2000.**

  The fish community monitored in 2002 was characterized by an absence of intolerant species, low diversities of darters and shiners, and high percentages of tolerant fish and omnivores+herbivores (NCDWQ, in review). **Community composition was typical of streams with poor habitat, open canopy, and excessive nutrients. The fish community was rated Poor.**

<u>King Creek</u>

- *King Creek at US 25.* Although this site is bordered by riparian forest and had a moderate habitat score (64 out of 100), it is just below the Kenmure Golf Course, where there is no woody riparian vegetation and the creek has been channelized. At the sampling site, there was a large amount of bedrock, but other substrates, from boulder to sand/silt were present. However, organic microhabitat was very limited. The benthic community was sampled in October 2000, and had a limited number of EPT taxa (10) and a moderate BI (5.26). **Like the upper site on Bat Fork, it was dominated by pollution-tolerant taxa, but also had a few intolerant taxa.**

<u>Reference Site</u>

- *Unnamed Tributary to Crab Creek at Crab Creek Rd.* This site had a similar habitat score (72) to that of upper Bat Fork, and its substrate was dominated by bedrock, although smaller substrates were also present. Unlike upper Bat Fork or King Creek, it had abundant organic microhabitat, with leafpacks, sticks, large woody debris, and undercut banks/rootmats. **Its benthic community (sampled in October 2000) was rated Excellent**, with high EPT richness (25) and a low BI (3.87).

6.3.2 Summary of Conditions and Nature of Impairment

Bat Fork showed signs of increasing stress from upstream to downstream. Although most sites could not be rated, they were all characterized by an impacted benthic community, dominated by pollution-tolerant taxa. Few sensitive (or intolerant) taxa were present at the upper site (Tabor Rd.) on Bat Fork. In comparison, upper Bat Fork's reference site (unnamed tributary to Crab Creek) was characterized by a benthic community typical of clean mountain streams, with a diversity of sensitive taxa. At the two downstream sites on Bat Fork, no sensitive taxa were present, and taxa indicative of lower dissolved oxygen appeared.

Habitat also worsened from upstream to downstream in Bat Fork. The upper site had a moderate amount of in-stream habitat, with relatively unembedded riffles and some organic microhabitat (sticks, undercut banks/root mats, and limited leafpacks and large woody debris). The two lower sites were channelized, and riparian vegetation was limited to scrubby vegetation growing on the stream banks. The bottom substrate was dominated by sand, riffles were non-existent or very embedded, and organic microhabitat was often very limited. As noted in Section 5.3.1, the lack of roughness in these channelized sections may magnify storm scour impacts; without bends, large woody debris, and rocks, organic microhabitats and macroinvertebrates can be more easily flushed through the system. This may have contributed to the community impacts seen in Bat Fork below Dunn Creek, which was sampled after heavy stormflows in 2001. The lowest site on Bat Fork was sampled on the same date, but there was little difference in the community between 2000 and 2001, so it is unlikely that stormflow scour impacted this site.

The King Creek benthic community was similar to that of upper Bat Fork—including some sensitive taxa but dominated by pollution-tolerant taxa. Organic microhabitat was very limited here, and the entire upstream watershed is in a golf course development, streams cleared of most riparian vegetation and often channelized.

6.4 Characterization of Chemical and Toxicological Conditions

6.4.1 General Water Quality Characterization

pH ranged between 6.0 and 7.4 at the integrator location at Airport Rd. (Table 6.3). Specific conductance was high (70 to 85 µS/cm) compared to that of forested mountain streams (Caldwell, 1992) (Table 6.3). **Fecal coliform bacteria levels were well above the NC standard of 200 colonies/100 mL**; the geometric mean of 5 samples collected in 30 days was 463 colonies/100 mL. Dissolved oxygen levels were adequate for aquatic life, but nutrient levels were high compared to forested mountain streams (Simmons and Heath, 1982). Although total phosphorus measured five times during this study in 2001 had a median below the detection limit of 0.02 mg/L, monthly VWIN data (orthophosphate as P) reveal higher levels for 2000 and 2001 at the upstream location of Tabor Rd.; the median phosphorus was 0.05 mg/L (Table B.12, Appendix B). Baseflow total nitrogen measured during this study had a median of 1.7 mg/L, which is higher than that expected for unpolluted streams in the mountains (Simmons and Heath, 1982).

A data sonde was deployed at Tabor Rd. for two weeks to measure specific conductance, pH, temperature, and dissolved oxygen levels over time. Dissolved oxygen was adequate, ranging from 6.3 to 7.9 mg/L. Specific conductance ranged widely from 11 to 99 µS/cm and pH fluctuated between 5.6 and 6.7 (Table B.3, Appendix B). Since it rained during this period and GE discharges its stormwater to Bat Fork above Tabor Rd., these changes could be due to stormwater inputs from GE.

6.4.2 Stressor and Source Identification: Organic Chemicals

Water quality samples were collected from Bat Fork at Tabor Rd. to determine the level of organic contaminants in baseflows below General Electric's (GE) groundwater contamination site. **Tetrachloroethene was the only organic contaminant found by DWQ, and measured concentrations (1.4 and 1.55 µg/L) were well below the EPA Tier II chronic benchmark of 98 µg/L**. Chronic toxicity bioassays were performed on two baseflow samples, and they passed.

Table 6.3 Water Quality Results for Bat Fork at Airport Rd. (MUBF02)

PARAMETER	BASEFLOW					STORMFLOW	
	N	MAX	MIN	MED	MEAN	N	VALUE
Nutrients (mg/L)							
Ammonia Nitrogen	5	<0.1	<0.1	<0.1	<0.1	1	0.6
Total Kjeldahl Nitrogen	5	1.3	0.4	0.8	0.8	1	<0.1
Nitrate+Nitrite Nitrogen	5	1.42	0.70	1.05	1.09	1	1.29
Total Nitrogen	5	2.3	1.6	1.7	1.9	1	1.3
Total Phosphorus	5	0.04	<0.02	<0.02	<0.02	1	0.04
Other Conventional							
DO (mg/L)	6	10.8	7.0	7.9	8.3	1	9.9
pH (Standard Units)	6	7.4	6.0	7.0	6.8	1	5.7
Specific Cond (µS/cm)	6	85	70	83	81	1	80
Hardness, total (mg/L)	5	34.0	22.7	28.0	28.5	1	26.0
Total Suspended Solids (mg/L)	5	8.3	3.0	6.8	6.2	1	3.0
Total Dissolved Solids (mg/L)	5	69	33	67	61	1	71
Turbidity (NTU)	5	8.9	4.0	7.9	7.3	1	NA
Calcium (mg/L)	6	7.07	5.56	6.07	6.12	1	5.57
Magnesium (mg/L)	6	2.18	1.88	1.97	2.00	1	1.81
Fecal Coliform Bacteria (colonies/100 mL)	5	580	350	490	463[1]		

[1] Mean value for fecal coliform bacteria is the geometric mean

GE also collected baseflow samples in September 2000 and 2001, and organic analysis detected tetrachloroethene at similar levels (Table B.14, Appendix B). No other organic contaminants were measured above detection limits.

One stormflow sample was analyzed for pesticides and other organic contaminants in Johnson Drainage Ditch; no organic contaminants were detected (Table B.21, Appendix B).
Like Devils Fork (see Section 5.4.2), upper Dunn Creek was sampled during winter baseflows on one date in order to determine the possibility of groundwater contamination by pesticides. Analysis for organochlorines, organophosphate insecticides, acid herbicides, and nitrogen pesticides was performed, but no pesticides were detected. These analyses (with the exception of nitrogen pesticides) were also performed on one baseflow sample in August 2000 in Bat Fork at Airport Rd., and no pesticides were detected.

6.4.3 Stressor and Source Identification: Metals

Selected metals concentrations measured in the watershed were compared to the chronic and acute EPA NAWQC and Tier II criteria (screening values) that were adjusted for mean hardness. Table 6.4 presents baseflow data for the integrator location and all stormflow data. Both median baseflow concentrations and the one stormflow sample from Bat Fork at Airport Rd. were below benchmark values, although 1 of 6 baseflow samples exceeded the chronic benchmarks for zinc and cadmium. The one stormflow sample analyzed from Johnson Drainage Ditch had a zinc level above the acute benchmark. Metals were sampled in baseflows in King Creek, but no metal value was above benchmark values.

Metals were analyzed in baseflows below Tabor Rd. in order to determine impacts from GE's contaminated groundwater plume (Table B.27, Appendix B). No metals were found above screening values. VWIN metals for this site were also below benchmark levels, although 9% of lead values were above the chronic benchmark.

Table 6.4 Selected Metals in Bat Fork and Johnson Drainage Ditch and Comparison Values of the French Broad River at Rosman and EPA Screening Levels[1,2,3]

Site	Total metal concentration (ug/L)					
	Cadmium	Copper	Lead	Silver	Zinc	Calculated Hardness (mg/L)[4]
NCDWQ Class C Standard	**2.0**	**7**	**25**	**0.06**	**50**	
Bat Fork at Airport Rd. (MUBF02)						
3/12/2001--stormflow	<0.1	1	<1	<0.5	9.6	21.4
Adjusted acute benchmark	0.8	3	11	0.3	32.4	
Baseflow median (n=6)	0.1	1	<1	<0.5	12.2	23.3
Adjusted chronic benchmark	0.8	3	0.5	0.4	34.8	
Johnson Drainage Ditch at US176 (MUJD08)						
3/12/2001--stormflow	0.3	2	1	<0.5	**54.4**	19.3
Adjusted acute benchmark	0.7	3	10	0.2	29.7	
French Broad River at Rosman:						
median of 53 samples collected between 1/93 and 12/97		**3**			16.0	

[1] Baseflow values and French Broad River medians ≥ the chronic benchmark and stormflow values ≥ the acute benchmark are in bold type. If the value was < the DL, it is listed as "<DL".

[2] Chronic and acute benchmarks for all metals except Ag are EPA NAWQC values. Those for Ag are EPA Tier II Values. Benchmarks were adjusted for site-specific hardness.

[3] Metals listed are those with at least one sample from the Mud Creek watershed above the screening level.

[4] Hardness calculation=($[Ca^{2+}]$ X 2.497) + ($[Mg^{2+}]$ X 4.118). Data not available for French Broad River.

North Carolina has standards or action levels for the protection of aquatic life for some metals. In general, these values are higher than chronic and acute EPA criteria, which are adjusted for hardness. DWQ median baseflow metal values were below these levels; zinc in the stormflow sample from Johnson Drainage Ditch was above the NC action level, and 1 of 6 baseflow samples at the integrator location on Bat Fork had concentrations above the DWQ benchmark for zinc, iron, or cadmium.

6.4.4 Stressor and Source Identification: Suspended Sediment

Suspended sediment concentrations (SSC) were measured during storms in Bat Fork at Tabor Rd. (median of 331 mg/L, n=4), Bat Fork at Airport Rd. (median of 286 mg/L, n=6), in lower Dunn Creek (median of 317 mg/L, n=4), and in Johnson Drainage Ditch at 7th Ave. (median of 77 mg/L, n=6). For storms that produced samples at both Bat Fork sites, SSC was often higher at the upstream site (Tabor Rd.). See Section 2.2 in Appendix B for more information.

6.5 Channel and Riparian Area Summary

Most of Bat Fork was walked, and riparian and channel conditions were observed. More cursory examinations of stream and riparian conditions were performed for some of the tributaries of Bat Fork.

Channel and riparian area description

Much of Bat Fork is an unstable system, impacted by multiple factors. The headwater section of Bat Fork is of moderate gradient and begins below a small lake, after which it parallels a road for approximately 1,000 ft; here it has been channelized and is highly incised. It enters a small residential wooded area and then emerges in a cattle pasture near Roper Rd., where cattle have access for 0.5 mi and stream banks are extremely degraded (Figure 6.2).

Figure 6.2 Pasture along Bat Fork near Roper Rd.

Figure 6.3 Channelized section of Bat Fork.

Below this pasture and US 176, the creek enters General Electric property, which borders Bat Fork for approximately 0.7 mi to Tabor Rd. Here, it alternates between a rip-rapped ditch and a low gradient, stable meandering stream bordered by riparian forest. A beaver dam was recently breached, and large amounts of sand in the drained beaver pond above had the potential to move to the stream downstream of the dam.

Below Tabor Rd. and General Electric, Bat Fork flows through agricultural (corn, beans, tomatoes, peppers, cattle pasture) and residential areas. Here, its 100-year floodplain widens out, ranging from 100 to 1500 ft wide. Like upper Mud Creek, it has been channelized (IPSI identifies almost the entire length of Bat Fork below Tabor Rd. as channelized) and riparian vegetation is generally limited to a thin band of invasive shrubs and herbaceous vegetation. Recent dredging and bank scraping was observed occasionally. Stream banks are high and often vertical (Figure 6.3), and there are occasional bank blowouts along this channelized section. As it nears Airport Rd., the channel becomes extremely wide and deep, and beavers dam the stream multiple times.

A geomorphological assessment was performed by the Stream Restoration Institute of North Carolina State University on Bat Fork near Crest Rd. (see Figure 6.1) (NC Stream Restoration Institute, 2001a). The assessment revealed that Bat Fork is laterally unstable, eroding its banks and providing a source of sediment.

Bat Fork is incised, and this is likely due to channelization (historic and current), removal of woody riparian vegetation, and subsequent downcutting through the substrate. Bat Fork may be in a stage of channel widening (NCSU, 2001a). Incised streams that have begun widening generally continue to do so until the channel width is sufficient to allow for the stabilization of slumped banks and the development of a new geomorphic floodplain within the banks (Schumm et al., 1984; Simon 1989; Simon and Darby, 1999).

<u>In-stream habitat</u>

Sand/silt is a dominant substrate throughout Bat Fork. Larger inorganic substrate, such as cobble and gravel, and riffle-pool sequences are present in the upper, higher gradient sections of Bat Fork. Larger substrate and riffle-pool sequences disappear once the channel becomes very wide and deep (downstream of Upward Rd.).

Like in Mud Creek, the lack of riparian vegetation is reflected in minimal organic habitat. Large woody debris, sticks, leafpacks, and suitable edge habitat (tree roots) are limited. Channelization and lack of riparian vegetation have decreased in-stream roughness, decreasing the stream's ability to catch organic microhabitats.

<u>Sediment and nutrient sources</u>

Aside from eroding stream banks, several sediment sources were noted. Many tributaries (e.g., Dunn Creek) are obvious sources of sand to Bat Fork; shelves of sand fan into the mainstem from these creeks. Land disturbance adjacent to Bat Fork and its tributaries left large areas of bare soil near the creek, and those sedimentation and erosion control measures used (if any) were not effective in preventing sediment delivery to the creek. Land disturbance was generally due to construction activity and private road development.

As noted above, cattle access to the Bat Fork mainstem was seen in the upper section. In addition, cattle had access to some tributaries of Bat Fork. A straight pipe from a residence was also noted, and it was reported to the Henderson County Department of Public Health.

<u>Tributaries</u>

The two larger tributaries of Bat Fork are King Creek and Dunn Creek. In its lower reaches, Dunn Creek has similar issues to Bat Fork—limited bank vegetation, sandy substrate, and channelization. In its upper reaches, Dunn Creek flows through apple orchard and pasture, and has a less modified channel. At its confluence with Bat Fork, King Creek is a wide and deep ditch with weedy bank vegetation and sandy substrate. In its upper reaches, it flows through some forested areas where it has better riparian vegetation and good in-stream habitat. However, these are interspersed with golf courses and camps, which have impounded the creek four times. The last impoundment is approximately 1.5 mi above King Creek's confluence with Bat Fork, and below this dam, King Creek has been channelized and has limited riparian vegetation. Meninger Creek, which meets King Creek below this last impoundment, does flow through a forested area, is relatively stable, and has good in-stream habitat. Smaller tributaries to Bat Fork are generally unstable and have very poor in-stream habitat.

6.6 Conclusions: Identification of Causes and Sources of Impairment

Impacted biological communities were noted throughout Bat Fork during the present study. Each stressor investigated during this study is evaluated below. See Section 3.5.1 for definitions of stressor types (e.g., cumulative cause of impairment).

6.6.1 Habitat Degradation Due to Sedimentation

Sedimentation is a cumulative cause of impairment.

Excess sediment deposition was evident throughout Bat Fork, although it was most problematic at those sites with the most impacted biological communities. Although sand and silt were the dominant substrates at the uppermost site at Tabor Rd., coarser substrate (boulder, cobble, and gravel) was still present in substantial amounts in riffle areas. Downstream, sand and silt increased to 70-85% of the substrate and riffle embeddedness increased. *Sedimentation is considered a cumulative cause of impairment for Bat Fork.*

<u>Sediment sources</u>. Sources of sediment are numerous and come from both in-stream and upland sources. Unstable and unvegetated banks of both Bat Fork and its tributaries are an important source of sediment. Bat Fork and some of its tributaries are incised and laterally unstable. These creeks have likely downcut to lower bed levels. Much of Bat Fork and its tributaries have been channelized, which is often accompanied by incision. The practice of clearing bank vegetation further destabilizes stream banks. Exposed loose soil erodes into streams during storm events, increasing suspended and bed load sediments. In addition, cattle have access to Bat Fork and some of its tributaries, and this causes banks to collapse and contribute sediment to these streams.

Upland sources of sediments are important in this watershed as well. Land disturbance for commercial and residential development provide sources of sediment primarily in the downstream half of Bat Fork (below Crest Rd.).

6.6.2 Habitat Degradation--Other Issues

> Lack organic microhabitat and lack of a diversity of depth and velocity combinations (riffles, pools, bends) are cumulative causes of impairment.

As in upper Mud Creek, other watershed-wide issues contribute to habitat degradation in Bat Fork. Extensive channelization over the past 150 years has led to channel "simplification"—a straighter channel with few bends, riffles, and pools. Conversely, meandering channels generally have a diversity of depth and velocity types, providing key habitats for aquatic organisms. Within a meandering channel, this diversity of depth and velocity provides channel roughness, or irregularity, that is important in catching organic microhabitats, such as sticks and leaves. Few meandering reaches remain in Bat Fork. In areas where the stream channel did meander below stream bank blowouts or within a less controlled channel, riffles and pools were more frequent.

Limited riparian vegetation was an issue for much of Bat Fork. In many agricultural areas, vegetation was limited to a thin fringe of invasive shrubs and herbaceous vegetation. This vegetation does provide a source of sticks and leafpacks important for benthic macroinvertebrates. However, undercut banks and large woody debris provided by trees were limited. Undercut banks and large wood not only provide habitat and a food source for aquatic organisms, but they also contribute to channel roughness, catching smaller organic microhabitats.

In lower Bat Fork (below Upward Rd.), the channel is a very wide and deep ditch, where beavers have constructed dams. These dams influence the dynamics of the system, altering stream bed substrate and slowing water velocity. These changes can impact the benthic community by eliminating key habitat; for example, without riffles, key taxa are eliminated from the system. The sampling site at Airport Rd. was thus not an ideal monitoring site, since it was within a set of beaver dams. However, in this lower section of Bat Fork, the channel is so straight and wide that there are virtually no riffles even where there is no beaver activity.

Habitat degradation of tributaries also impacts Bat Fork. Due to their role as colonization sources, tributaries are important in maintaining mainstem benthic populations. Benthic and fish populations are dynamic. Taxa can be lost through catastrophic events, such as stormflow scour, drought, and toxicants. Benthic recolonization after catastrophic events occurs through a number of mechanisms, with downstream drift considered the most important method of colonization (Smock, 1996). Thus, a stream benthic community is the sum of its watershed; if upstream sources are impacted, then the maintenance of a healthy stream community is limited. Above Airport Rd. (the lowest benthic monitoring station), upstream tributary sources are limited to Dunn Creek and very small tributaries. The small tributaries generally have poor habitat; they are very incised and sandy ditches. Dunn Creek has some acceptable habitat in its upper reaches, but near its confluence with Bat Fork, it is a wide sandy channel with very poor bank vegetation.

These habitat issues likely act in concert with sedimentation to impact the aquatic community. *Lack of suitable in-stream habitat, including organic microhabitat and a diversity of depth and velocity combinations (riffles, pools, bends), is considered a cumulative cause of impairment.*

6.6.3 *Toxicants*

Exposure to toxicants is a cumulative cause of impairment.

Benthic community analysis provides some evidence that toxicants impact the benthic community of Bat Fork. The benthic community demonstrated typical characteristics of toxic stress—toxicant-intolerant taxa, such as stoneflies, were absent and more tolerant taxa were dominant.

Limited water chemistry analysis provides evidence that organic contaminants from GE's contaminated groundwater plume do reach Bat Fork, but levels appear to be too low to cause toxicity. It is possible that continuous exposure to low levels of these contaminants contribute to sub-lethal impacts to the biological community. Metal concentrations throughout Bat Fork were generally lower than benchmark levels, and it is unlikely that high metal levels are problematic in Bat Fork. Since only one storm sample was analyzed from Bat Fork, the role of stormflow chemistry in toxicity is unknown. Johnson Drainage Ditch had a storm sample with a high zinc concentration, but this site was below sites where benthic communities were monitored.

Most of the pesticide monitoring performed during the growing season was in the Clear Creek and upper Mud Creek subwatersheds; there were only two baseflow samples and one stormflow sample analyzed for pesticides in the Bat Fork subwatershed, and no pesticides were detected in these samples. Biological, chemical, and toxicological data in conjunction with land use patterns in the Clear Creek and upper Mud Creek subwatersheds provide evidence that pesticides used on row crops and apples may severely impact the benthic community. Since tomatoes/peppers are grown along Bat Fork and there is a large area of apple orchard in Dunn Creek, there is potential for pesticide toxicity in Bat Fork, as well.

The Kenmure and Highland Lake Golf Courses are both in the King Creek drainage, and it is possible that pesticides from these intensively managed areas could reach streams. However, the benthic sampling locations on Bat Fork were above the King Creek confluence. Likewise, any impacts from the five wastewater treatment plants (WWTPs) in the King Creek drainage are limited to Bat Fork below King Creek. Lakewood RV Resort on Dunn Creek and GE on Bat Fork were the only WWTPs that were upstream of the Bat Fork benthic sites. GE discharged treated contaminated groundwater only until October 2000, and it received a Notice of Violation for exceeding its copper, zinc, and total suspended solids limits in April 2000. However, VWIN copper and zinc levels for Bat Fork at Tabor Rd. (less than 0.5 mi below the WWTP outfall) were all below benchmark levels. Lakewood RV Resort exceeded its total suspended solids limit one month, but was otherwise in compliance; due to its size, it is not likely a problem for Bat Fork biological communities.

Based on analysis of benthic macroinvertebrate data, exposure to toxicants is considered a cumulative cause of impairment for Bat Fork. The source or type of toxicants cannot be determined with the limited data available.

6.6.4 *Other Possible Stressors*

<u>Drought</u>

The extended drought that began mid-1998 decreased flows in the Mud Creek watershed, and may serve as an additional stressor to aquatic invertebrate communities (see Section 4.6.4).

However, it is unlikely that low flows are a key stressor; reference sites in the adjacent Crab Creek watershed sampled during the same period (see Sections 5.3 and 6.3) were rated Good or Excellent.

<u>Fecal coliform contamination and nutrients</u>

High fecal coliform bacteria levels were found in Bat Fork. Although these can indicate a risk to human health, they do not directly impact biological community condition. The most likely sources of these high levels were cattle that were allowed access to Bat Fork and its tributaries and straight piped waste from residences on Bat Fork and its tributaries.

Water chemistry data provide evidence of high nutrient levels, and obvious sources of organic waste were observed in Bat Fork (from cattle and a straight pipe). The fish community sampled in 2002 was impacted by excessive nutrients. However, benthic community analysis did not indicate problems with nutrient enrichment, so nutrients are not considered a stressor for Bat Fork.

<u>GE impacts</u>

Although there is no evidence that groundwater contamination at the GE site is a source of toxicity, historical and current issues may impact the benthic community. In 1989, sampling below GE at Tabor Rd. revealed a severely impacted benthic community (EPT richness = 2); in 2000, the benthic community was more diverse (EPT richness = 14), but still dominated by taxa tolerant of stress. In 1995, the industrial processing water from GE was no longer discharged to Bat Fork, and this may account for the recovery seen in the benthic community. Beginning in 1997, GE was permitted to discharge 0.5 mgd of treated contaminated groundwater to Bat Fork; this discharge was eliminated in October 2000. Stormwater from this 80 acre site does discharge to Bat Fork, and this could still impact the benthic community through both scour and water quality. Bat Fork's recovery from past impacts is likely very slow due to the lack of suitable upstream sources—its headwaters flow from a lake, below which there is often a very different benthic community, and then flow through 0.5 miles of stream with cattle access.

<u>Colonization sources</u>

> Lack of upstream colonization sources is a cumulative cause of impairment.

Limited recolonization potential from within the watershed is a concern. The quality of Bat Fork tributaries as colonization sources is limited due to impoundments, severe habitat degradation (see Section 6.6.2), and possible pesticide impacts (especially Dunn Creek). Even if some of the problems in Bat Fork are solved, the ability of this stream to establish and maintain a healthy biological community is limited by the quality of its upstream colonization sources. ***Lack of upstream colonization sources is considered a cumulative cause of impairment.***

6.6.5 Conclusion

Multiple stressors are clearly important in Bat Fork, but their relative contribution cannot be differentiated with the available data. Exposure to toxicants, lack of upstream colonization sources, and habitat degradation due to sedimentation and lack of suitable in-stream habitat, including organic microhabitat and a diversity of depth and velocity combinations (riffles, pools, bends), are considered cumulative causes of impairment.

At the upstream site (Tabor Rd.), in-stream habitat was likely sufficient to host a diverse benthic community. Other stressors, such as lack of upstream colonization sources and slow recovery from past impacts, must be important at this site. Downstream in the channelized section of Bat Fork, however, habitat is poor and likely much more important in benthic impairment.

Section 7
Results and Conclusions: Lower Mud Creek Subwatershed

Lower Mud Creek receives the combined flows from the upper Mud Creek, Bat Fork, Clear Creek, and Devils Fork subwatersheds, as well as that of Hendersonville and part of Laurel Park. It is considered impaired for its entire length. DWQ's Biological Assessment Unit performed studies of the Hendersonville wastewater treatment plant's (WWTP) impact on the benthic community of Mud Creek in 1985, 1992, and 1997. Although a decline in benthic community integrity was observed below the WWTP in 1985, there was no distinct decline seen in later years. Fair or Poor benthic communities were documented at four sites on lower Mud Creek, including those above and below the WWTP as well one upstream in Hendersonville (7th Ave.) and another near Mud Creek's mouth (US 25).

The fish community of Mud Creek at 7th Ave. was sampled by DWQ in 1997. Mud Creek was rated Poor and had an abundance of omnivores and herbivores, only one intolerant taxon, and many non-native and tolerant fish; community composition was indicative of habitat degradation and disturbance typical of urban watersheds. The Tennessee Valley Authority also sampled fish at Berkley Rd. and US 25 in 1997; they found Poor-Fair fish communities.

The Volunteer Water Information Network (VWIN) monitors water quality at three sites in this subwatershed—Mud Creek in Hendersonville (7th Ave.) and near its mouth (N. Rugby Rd.) and Brittain Creek, a tributary to Mud Creek in Hendersonville. For the period of 1992-1999, Mud Creek at N. Rugby Rd., the most downstream location, had the highest median turbidity levels of any Mud Creek watershed site, and nutrient levels increased from 7th Ave. to N. Rugby Rd.

7.1 Key Stressors Evaluated in the Lower Mud Creek Subwatershed

Plausible causes of biological impairment in the Mud Creek watershed were identified using both bioassessment and watershed-driven approaches (Figure 1.2). Biological community data, habitat information, and land uses and activities were considered to flag stressors for further investigation. Based on preliminary review, the following stressors were evaluated as the most plausible candidate causes of impairment in upper Mud Creek for further investigation:

1. <u>Habitat degradation due to sedimentation.</u> Habitat degradation due to sedimentation manifests itself in the loss of pools, burial of riffles, and high levels of substrate instability. Excess sedimentation was historically listed as a problem parameter for Mud Creek on the 303(d) list.

2. <u>Toxicants.</u> Multiple sources of toxicants exist in the watershed. Hendersonville and parts of Laurel Park drain to Mud Creek, so there is significant potential for a wide variety of toxicants to enter Mud Creek and its tributaries during storm events, from spills, unauthorized discharges to the stormwater system, or contaminated groundwater. Pesticides may enter lower Mud Creek from residential areas and agricultural portions of Clear Creek, Devils Fork, and upper Mud Creek.

7.2 Monitoring Locations

Monitoring site locations as listed below were chosen in order to characterize stream integrity, identify stressors, and pinpoint sources of these stressors. Benthic invertebrate communities, water chemistry, and sediment chemistry were evaluated in this study primarily during the period of 2000-2001 (Figure 7.1, Table 7.1). VWIN chemical data were also used in this analysis.

<u>Mud Creek Mainstem (Upstream to Downstream)</u>

- *Mud Creek at White St.* (MUMC33). This sampling site is downstream from tomato and other vegetable fields and was sampled for pesticides.
- *Mud Creek at 7th Ave. (SR 1647)* (MUMC24). This site is within Hendersonville but above Bat Fork, Johnson Drainage Ditch, and Clear Creek. It was sampled for benthic macroinvertebrates, fish, and suspended sediment. It is a VWIN chemistry site.
- *Mud Creek at Berkley Rd. (SR 1508)* (MUMC06). This site is downstream of most of the downtown area of Hendersonville and the main stormwater system inputs. It is also downstream of the confluence with Johnson Drainage Ditch, which carries the flow of Devils Fork and Bat Fork. It was sampled for benthic macroinvertebrates and stormflow water chemistry (urban contaminants including metals, organics, and pesticides) and acute toxicity. An SPMD was analyzed for pesticides and other organic contaminants. A data sonde was deployed for two weeks to measure dissolved oxygen over time.
- *Mud Creek at Balfour Rd. (SR 1508)* (MUMC49). This site is approximately 1 mi downstream of MUMC06 and below the Hendersonville wastewater treatment plant and the Clear Creek confluence. It was sampled for benthic macroinvertebrates.
- *Mud Creek at US 25* (MUMC34). This is the lowest benthic sampling location on Mud Creek. Sediments were sampled here for toxicity and chemistry.
- *Mud Creek at N. Rugby Rd.* (MUMC05). This is the lowest site on Mud Creek and the integrator location for the subwatershed. It thus integrates all impacts from the entire Mud Creek watershed. Water samples were collected for suspended sediment, integrator parameters, and pesticides. It is also a VWIN sampling location. A data sonde was deployed for two weeks to measure dissolved oxygen.

<u>Tributaries to Mud Creek</u>

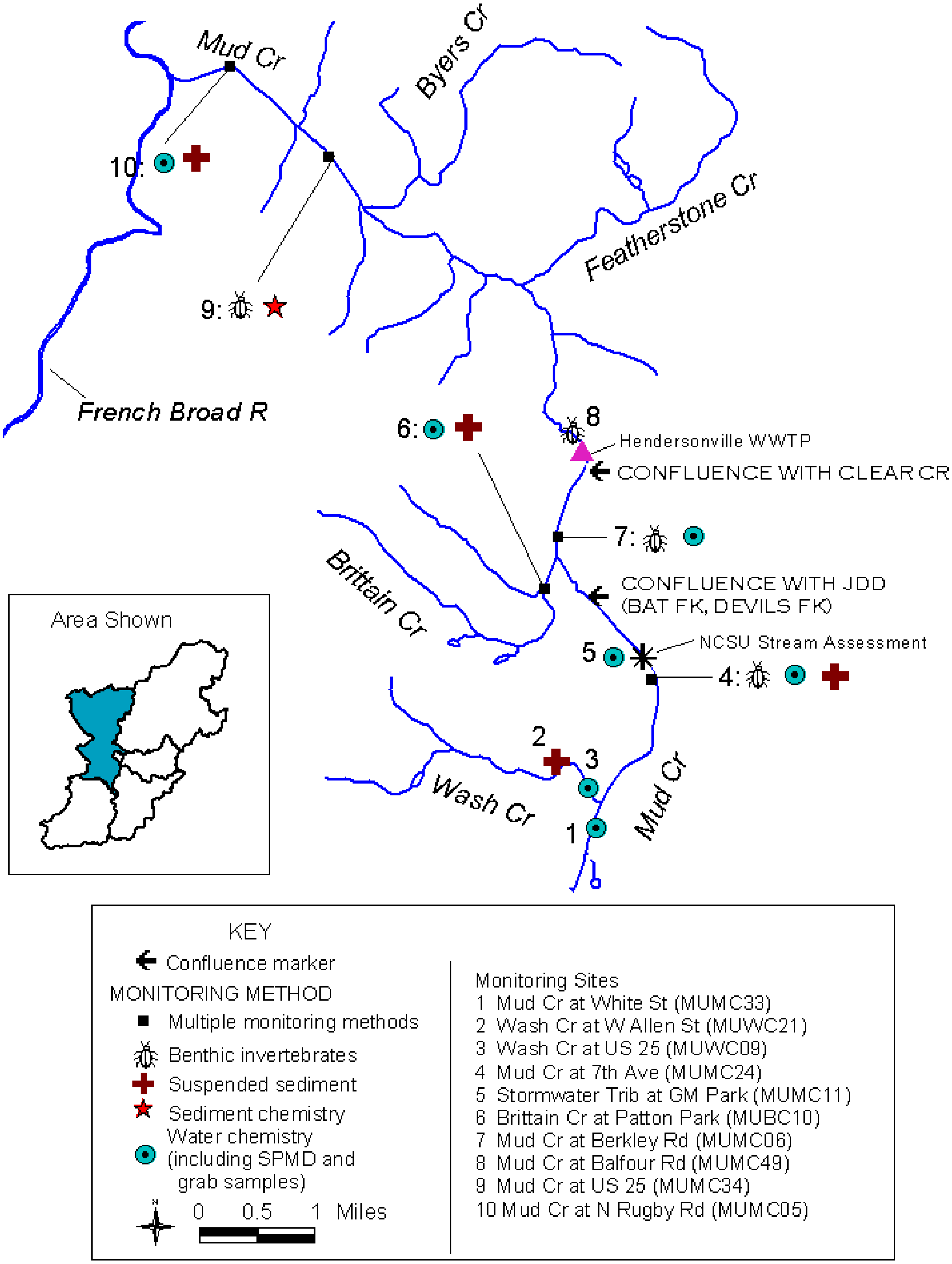
- *Wash Creek at W. Allen St.* (MUWC21). This site was a suspended sediment monitoring location.
- *Wash Creek at US 25* (MUWC09). This is just above the confluence with Mud Creek and carries stormwater runoff from central west downtown Hendersonville. Stormflow was analyzed for acute toxicity, pesticides, other organic contaminants, and metals.
- *Stormwater Tributary at Green Meadows Park* (MUMC11). This small perennial stream receives storm runoff from the east central Hendersonville, which is largely an industrial zone. Stormflow was analyzed for acute toxicity, pesticides, other organic contaminants, and metals.
- *Brittain Creek at Patton Park* (MUBC10). This site receives stormwater runoff from the northern end of Hendersonville. Stormflow samples were analyzed for suspended sediment, metals, organics, pesticides, and acute toxicity. This is also a VWIN site.

Table 7.1 Summary of Monitoring Approaches Used at Primary Sampling Sites, Lower Mud Creek Subwatershed

	Station Code	Location	Benthos	Fish	DWQ Water Quality[1]	SPMD	Data Sonde	VWIN Water Quality[1]	Suspended Sediment	Bed Sediment Quality
Mud Cr. Mainstem	MUMC33	*Mud Creek at White St.*			✓					
	MUMC24	*Mud Creek at 7th Ave.*	✓	✓				✓	✓	
	MUMC06	*Mud Creek at Berkley Rd.*	✓		✓	✓	✓			
	MUMC49	*Mud Creek at Balfour Rd.*	✓							
	MUMC34	*Mud Creek at US 25*	✓							✓
	MUMC05	*Mud Creek at N. Rugby Rd.*			✓+		✓	✓	✓	
Mud Cr. Tributaries	MUWC21	*Wash Creek at W. Allen St.*							✓	
	MUWC09	*Wash Creek at US 25*			✓					
	MUMC11	*Stormwater Tributary at Green Meadows Park*			✓					
	MUBC10	*Brittain Creek at Patton Park*			✓			✓	✓	

[1] Grab samples and/or repeated field measurements.
\+ Integrator station.

Figure 7.1 Monitoring Sites in the Lower Mud Creek Subwatershed



7.3 Characterization of the Biological Community and Stream Habitat

7.3.1 Description

Selected habitat and biological characteristics for each site sampled during the study are shown in Table 7.2. See Section 3.2.2 and Appendix A for additional details. A narrative summary of conditions at each site follows. Benthic sampling performed in October 2001 was one week after heavy rains. Sampling performed in July 2000 in Mud Creek at Balfour Rd. and US 25 was within one day of a 1,100 gallon sewage spill at US 64.

- *Mud Creek at 7th Ave.* This site had a low habitat score (mean score of 41 out of 100), with very sandy bottom substrate (mean of 88% sand+silt), infrequent and embedded riffles, and collapsing stream banks. In-stream habitat was sparse but varied; organic microhabitats such as sticks, leafpacks, and large wood were present. **In July 2000, the benthic community was rated Fair but showed a distinct improvement from 1997 when it was rated Poor**, with an increase in EPT richness (from 5 to 22 taxa) and a decrease in BI (from 6.80 to 5.80). There were a few pollution intolerant taxa, but tolerant taxa dominated the community. **In October 2001, the benthic community rating plummeted back to Poor**, with lower EPT richness (10 taxa) and a higher BI (7.09). Most intolerant taxa were lost from the site, and the most dominant midge was toxicity-tolerant. Midge taxa richness also declined from 16 to 6 taxa.

  The fish community monitored in 2002 was characterized by low diversities of darters and shiners and high percentages of tolerant fish and omnivores+herbivores (NCDWQ, in review). **Community composition was typical of streams with poor habitat and excessive nutrients. The fish community was rated Poor.**
- *Mud Creek at Berkley Rd (above WWTP).* This site had a similar habitat score (40) to that at 7th Ave., but it had sandier substrate (100% sand+silt). The only riffle present was provided by rip-rap under the bridge. Organic microhabitat consisted of undercut banks/root mats and large woody debris, and small sticks and leafpacks were rare. When sampled in July 2000, it showed a distinct improvement from 1997, with an increase in EPT richness (from 5 to 14 taxa) and a decrease in BI (from 7.10 to 6.36). **The benthic rating improved from Poor to Fair.**
- *Mud Creek at Balfour Rd (below WWTP and Clear Creek confluence).* This site had the worst habitat in Mud Creek, with a habitat score of 34. Like that above the WWTP, bottom substrate was 100% sand+silt. The only riffle present was provided by rip-rap under the bridge. It had some organic microhabitat, with large woody debris, sticks, leafpacks, and undercut banks/root mats. When sampled in July 2000, it also showed a distinct improvement from 1997, with an increase in EPT richness (from 8 to 12 taxa) and a decrease in BI (from 7.09 to 6.60). **The benthic rating improved from Poor to Fair.**
- *Mud Creek at US 25.* This site had a low habitat score (43) as well, and bottom substrate was sandy (90% sand+silt). There were no riffles present, but organic microhabitat was diverse and plentiful. **When sampled in July 2000, it showed a decline in community integrity from 1997; the rating changed from Fair to Poor.** It had a slight decrease in EPT richness (12 to 10 taxa) and an increase in BI (6.72 to 7.06). A number of midge taxa tolerant of toxicity and multiple stressors were abundant.

Table 7.2 Selected Benthic Community and Habitat Characteristics at Study Sites in the Lower Mud Creek Subwatershed[1]

Site	Date	Substrate % sand and silt[2]	In-stream Structure Score (of 20)[3]	Embedded-ness Score (of 15)[4]	Habitat Score Total (of 100)[5]	EPT Richness[6]	EPT Biotic Index[6]	Biotic Index[6]	Bioclassification[6]
Mud Creek at 7th Ave.	9/8/97	90		3	57	5	6.80	6.80	Poor
	7/11/00	90	8	3	34	22	4.70	5.80	Fair
	10/03/01	85	10	4	48	10	5.92	7.09	Poor
Mud Creek at Berkley Rd.	9/12/85	60				10	5.60	6.99	Fair
	7/7/92	100				10			Poor
	9/8/97	85		3		5	6.24	7.10	Poor
	7/11/00	100	8	3	40	14	5.31	6.36	Fair
Mud Creek at Balfour Rd.	9/12/85	90				3	7.17	7.74	Poor
	7/7/92	100				7			Poor
	9/8/97	85		3		8	5.84	7.09	Poor
	7/12/00	100	8	3	34	12	5.46	6.60	Fair
Mud Creek at US 25	9/9/97	60		3	60	12	5.70	6.72	Fair
	7/13/00	90	11	3	43	10	5.70	7.06	Poor

1 Limited data are available for samples from 1997, 1992, and 1989.
2 Based on visual estimate of substrate size distribution.
3 Visual quantification of the of in-stream structures present, including leafpacks and sticks, large wood, rocks, macrophytes, and undercut banks/root mats.
4 Estimation of riffle embeddedness, or the degree which a riffle's larger inorganic substrate is buried by sand and silt. The higher the score, the less embedded.
5 See Section 3.2.4 for a list of component factors.
6 See Section 3.2.4 for description. Seasonally corrected scores are presented for EPT Richness and Biotic Index.

7.3.2 Summary of Conditions and Nature of Impairment

Lower Mud Creek showed signs of increasing stress from upstream to downstream when all sites were sampled in 2000. At each site on lower Mud Creek, the benthic community was dominated by pollution-tolerant taxa; however, a few sensitive (or intolerant) taxa were present at the upper Hendersonville site (7th Ave.). At each site along lower Mud Creek except the lowest site (US 25), benthic community integrity increased from when last sampled in 1997. This may be related to a decrease in storm-driven non-point source impacts due to low rainfall in 2000.

It is unlikely that the sewage spill on Mud Creek at US 64 on July 12, 2000 had much impact on the downstream benthic communities at Balfour Rd. (sampled July 12) and US 25 (sampled July 13). The site at Berkley Rd., less than one mile upstream of Balfour Rd., was sampled the day before the spill and had a benthic community very similar to that at Balfour Rd. Impacts from the spill were likely minimized due to dilution; Balfour Rd. and US 25 are two and seven miles downstream of the spill location, respectively.

When sampled in October 2001, the upper Hendersonville site (7th Ave.) showed a distinct decline in benthic integrity from 2000. The community was characterized by more limited EPT richness and a lack of sensitive taxa, echoing the benthic community character at all sites below the uppermost site on Mud Creek in October 2001. The urban 7th Ave. site may have suffered more significant impacts from the week's previous rain than other sites; there was a notable decrease in midge taxa richness and abundance from both the 2000 7th Ave. and the October 2001 upstream site samples. However, some of the impacts seen in 2001 may be due to toxicity—the loss of sensitive taxa and increase in toxicity-tolerant taxa are both typical impacts of toxicity. The fish community sampled in 2002 was rated Poor, suffering from high nutrients and degraded habitat.

Habitat in lower Mud Creek was poor, characterized by very sandy substrate, infrequent and embedded riffles, and unstable stream banks. Organic microhabitat was generally present but limited; this was likely due in part to a band of trees along the banks that provide some roughness (undercut banks, roots, large woody debris) and smaller substrate (sticks, leafpacks).

7.4 Characterization of Chemical and Toxicological Conditions

7.4.1 General Water Quality Characterization

pH ranged between 6.8 and 7.4 at the integrator location at N. Rugby Rd. (Table 7.3). Specific conductance was high (80 to 107 µS/cm) compared to that of forested mountain streams (Caldwell, 1992). Fecal coliform bacteria levels were below the NC standard of 200 colonies/100 mL; the geometric mean of 5 samples collected within a period of 30 days was 49 colonies/100 mL. Dissolved oxygen levels were adequate for aquatic life, but nutrient levels were very high compared to forested mountain streams (Simmons and Heath, 1982). At N. Rugby Rd., total phosphorus measured five times during this study in 2001 had a median of 0.31 mg/L. Median baseflow total nitrogen measured during this study was 2.1 mg/L. Monthly VWIN data for 2000 and 2001 show a large increase in nutrient levels between 7th Ave. in

Hendersonville (above the WWTP and much urban input) and N. Rugby Rd. (below the WWTP and urban inputs). Median phosphorous (orthophosphate as P) increased from 0.03 to 0.18 mg/L, and nitrate increased from 0.50 to 1.20 mg/L (Table B.12, Appendix B).

Dissolved oxygen concentrations measured by data sondes in August and September of 2001 just above (Berkley Rd.) and 5 mi. below (N. Rugby Rd.) the Hendersonville WWTP at Berkley Rd. were similar, ranging from 5.4-8.8 mg/L above and 5.1-7.6 mg/L below (Table B.3, Appendix B).

Total residual chlorine (TRC) was sampled at a number of sites in the subwatershed (Table B.10, Appendix B). Of particular note is a tributary to Featherstone Creek, where there are three small WWTPs. Below each WWTP, TRC rose, peaking at 228 µg/L. The NC standard for chlorine is 17 µg/L.

Table 7.3 Water Quality Results for Lower Mud Creek at N. Rugby Rd. (MUMC05)

PARAMETER	BASEFLOW					STORMFLOW	
	N	MAX	MIN	MED	MEAN	N	VALUE
Nutrients (mg/L)							
Ammonia Nitrogen	5	0.2	<0.1	0.1	0.1	1	0.4
Total Kjeldahl Nitrogen	5	1.7	0.7	1.0	1.2	1	0.1
Nitrate+Nitrite Nitrogen	5	1.38	0.41	1.10	1.01	1	0.50
Total Nitrogen	5	2.9	1.6	2.1	2.2	1	0.6
Total Phosphorus	5	0.80	0.22	0.31	0.41	1	0.10
Other Conventional							
DO (mg/L)	6	10.6	6.7	8.3	8.5	1	7.9
pH (Standard Units)	6	7.4	6.8	7.1	7.1	1	7.2
Specific Cond (µS/cm)	6	107	80	94	94	1	67
Hardness, total (mg/L)	5	27.0	20.0	23.0	23.0	1	26.0
Total Suspended Solids (mg/L)	5	19.0	3.6	8.2	10.5	1	5.2
Total Dissolved Solids (mg/L)	5	84	68	75	75	1	66
Turbidity (NTU)	5	13.0	3.2	6.4	8.0	0	
Calcium (mg/L)	6	5.86	3.67	5.33	5.10	1	5.09
Magnesium (mg/L)	6	1.69	1.11	1.53	1.49	1	1.40
Fecal Coliform Bacteria (col/100 mL)	5	86	22	53	49[1]		

[1] Mean value for fecal coliform bacteria is the geometric mean

7.4.2 Stressor and Source Identification: Organic Chemicals

Organic contaminants were measured in a limited number of water samples from baseflows and/or stormflows at a number of locations on Mud Creek and several tributaries. Acute toxicity bioassays were performed on a subset of the stormflow samples.

- Pesticides were measured once in baseflows at two sites on Mud Creek—at N. Rugby Rd. (integrator site) and White St. in Hendersonville. No pesticides were detected.
- Pesticides, other organic contaminants, and acute toxicity were measured during one storm in March 2001 at three locations in Hendersonville—Wash Creek, a storm tributary in Green Meadows Park, and Brittain Creek. No pesticides or other organic contaminants were detected, and there was no evidence of acute toxicity.
- Multiple stormflows in Mud Creek below Hendersonville were measured for pesticides (n=3), other organic contaminants (n=2), and acute toxicity (n=3). No pesticides or other organic contaminants were detected, and there was no evidence of acute toxicity.

Bed sediment from Mud Creek at US 25 tested negative for chronic toxicity using *Hyallela azteca*. A number of organochlorine pesticides were found in the sediment (Table 4.4). Alpha and gamma-chlordane, DDE, and the sum of DDTs were at levels within the conservative benchmark range, indicating that it is possible but not probable that these pesticides singly cause toxicity. Sediments from a reference stream, the South Mills River, were also sampled; these sediments had some organochlorine pesticides, but only gamma-chlordane was present at levels above conservative benchmarks. Total polychlorinated biphenyls (PCBs) were found in Mud Creek sediments at levels well below any conservative benchmarks and reference sediment concentrations. Sediment analyses detected no polycyclic aromatic hydrocarbons (PAHs) or other semi-volatile organic contaminants.

A semi-permeable sampling device was deployed in Mud Creek below Hendersonville at Berkley Rd. for 17 days. Baseflow was the predominant flow type over most of the deployment period, but higher flows due to precipitation were present during 2 out of 17 days. A range of organic contaminants were detected, including organochlorine pesticides, PAHs, and PCBs, but all were below existing chronic benchmarks (Table B.4, Appendix B).

7.4.3 Stressor and Source Identification: Metals

Selected metals concentrations measured in the watershed were compared to the chronic and acute EPA NAWQC and Tier II criteria (screening values) that were adjusted for mean hardness. Table 7.4 presents data for the integrator site at Rugby Rd. and sites with stormflow data. Median baseflows from the Mud Creek integrator site were below benchmark values, with 1 of 6 samples exceeding the copper benchmark. One of four stormflow samples collected from the lower Mud Creek mainstem had a silver concentration above the acute benchmark. One of three Hendersonville tributary sites sampled during the 3/12/01 storm had high metal concentrations; copper and zinc were at least three times as high as the comparative acute benchmarks in the stormwater tributary to Mud Creek in Hendersonville at Green Meadows Park. However, an acute toxicity bioassay performed on this sample showed no evidence of toxicity.

2000-2001 VWIN data for Brittain Creek and Mud Creek at the integrator location include some samples with copper, zinc, and lead above the chronic benchmark, but the median levels are below the benchmarks (Table B.12, Appendix B). There is a notable increase in median copper, zinc, and lead concentrations in Mud Creek from 7th Ave. in Hendersonville to N. Rugby Rd.

North Carolina has standards or action levels for the protection of aquatic life for some metals. In general, these values are higher than chronic and acute EPA criteria adjusted for hardness.

Median baseflow metal values for data from the integrator location and VWIN sites were below these levels; only zinc and copper in the stormflow sample from the stormwater tributary at Green Meadows Park and silver in one baseflow sample from the integrator location exceeded these values.

Table 7.4 Selected Metals at Selected Sites[1] in the Lower Mud Creek Subwatersheds and Comparison Values of the French Broad River at Rosman and EPA Screening Levels[2,3,4]

Site	Total metal concentration (ug/L)					
	Cadmium	Copper	Lead	Silver	Zinc	Calculated Hardness (mg/L)[5]
NCDWQ Class C Standard	**2.0**	**7**	**25**	**0.06**	**50**	
Mud Creek at N. Rugby Rd. (MUMC05)						
3/12/2001--stormflow	0.6	<1	<1	**1.6**	5.1	18.5
Adjusted acute benchmark	0.7	3	10	0.2	28.6	
Baseflow median (n=6)	0.1	1	<1	<0.5	8.3	19.6
Adjusted chronic benchmark	0.7	2	0.4	0.4	30.2	
Mud Creek at Berkeley Rd. (MUMC06)						
Stormflow median (n=3)	<0.1	1	1	<0.5	7.0	19.3
Adjusted acute benchmark	0.7	3	10.1	0.4	29.7	
Unnamed stormwater tributary to Mud Creek at Green Meadows Park (MUMC11)						
3/12/2001--stormflow	<0.1	**10**	7	<0.5	**119.0**	19.3
Adjusted acute benchmark	0.7	3	10	0.2	29.7	
Wash Creek at S. Allen Rd. (MUWC09)						
3/12/2001--stormflow	<0.1	<1	<1	<0.5	14.5	19.3
Adjusted acute benchmark	0.7	3	10	0.2	29.7	
Brittain Creek At Patton Park (MUBC10)						
3/12/2001--stormflow	0.2	<1	<1	<0.5	13.2	19.3
Adjusted acute benchmark	0.7	3	10	0.2	29.7	
French Broad River at Rosman:						
median of 53 samples collected between 1/93 and 12/ 97		**3**			16.0	

1 Integrator sites and sites with stormflow monitoring.

2 Baseflow values and French Broad River medians ≥ the chronic benchmark and stormflow values ≥ the acute benchmark are in bold type. If the value was < the DL, it is listed as "<DL".

3 Chronic and acute benchmarks for all metals except Ag are EPA NAWQC values. Those for Ag are EPA Tier II Values. Benchmarks were adjusted for site-specific hardness.

4 Metals listed are those with at least one sample from the Mud Creek watershed above the screening level.

5 Hardness calculation=($[Ca^{2+}]$ X 2.497) + ($[Mg^{2+}]$ X 4.118). Data not available for French Broad River.

7.4.4 Stressor and Source Identification: Suspended Sediment

Suspended sediment concentrations (SSCs) were measured during six storms in Mud Creek at 7th Ave. and N. Rugby Rd., Wash Creek, and Brittain Creek. Brittain Creek had the highest median SSC (704 mg/L) in the entire Mud Creek watershed. Other median SSCs were 420 mg/L for

Wash Creek, 257 mg/L for Mud Creek at 7th Ave., and 208 mg/L for Mud Creek at N. Rugby Rd. See Section 2.2 in Appendix B for more information.

7.5 Channel and Riparian Area Summary

Most of lower Mud Creek was walked or kayaked, and riparian and channel conditions were observed. More cursory examinations of stream and riparian conditions were performed for some of the tributaries of lower Mud Creek.

<u>Channel and riparian area description</u>
The entire length of lower Mud Creek was likely channelized between 1840 and 1890 (see Section 2.4.1). It is a wide, deep, and sandy channel usually edged by a thin border of riparian vegetation (Figure 7.2).

As Mud Creek moves into the Hendersonville area, the channel is straight and about 30 ft wide, a result of extensive and repeated channelization. In Hendersonville, the creek runs through both commercial areas and undeveloped areas (city parks, private land). Within the commercial areas, businesses are often built up to the bank and a railroad borders the creek in some areas. Riparian vegetation ranges from a single line of trees to none with only rip-rap as bank stabilization. At one point, Mud Creek is covered by a large parking lot for approximately 600 ft. Banks are very high (up to 15 ft) and often built up with fill dirt, concrete blocks, and junk, and stormwater enters the creek through small ditches or stormwater pipes. Where city parks (Jackson Park and Hendersonville Wetlands Park) border Mud Creek, there is often a wide forested buffer. Many floodplain areas adjacent to Mud Creek in Hendersonville have been filled to decrease the likelihood of flooding.

Within the Hendersonville Wetlands Park, most of the flow of Johnson Drainage Ditch joins Mud Creek through a ditch that connects Johnson Drainage Ditch and Mud Creek. Flow from this ditch approximately doubles the flow of Mud Creek. Below this confluence, stream banks of Mud Creek become notably higher and less stable, reflecting the increased stress of stormflows from Johnson Drainage Ditch, which carries runoff from large commercial areas that drain to Bat Fork and Devils Fork (Figure 7.3).

Figure 7.2 Border of trees along lower Mud Cr.

Figure 7.3 Unstable banks on Mud Creek below Johnson Drainage Ditch

A geomorphological assessment was performed by the Stream Restoration Institute of North Carolina State University on Mud Creek in Hendersonville (Figure 7.1) (NC Stream Restoration Institute, 2001b). The assessment revealed that Mud Creek is laterally unstable, eroding its banks and providing a source of sediment. Fine sediment is aggrading in this wide, straight channel, deteriorating in-stream habitat.

Downstream of Hendersonville, Mud Creek flows through open land. Much of this land is crop and pastureland, although other uses such as wastewater spray fields, small commercial operations, and residences also occur along lower Mud Creek. Generally, the creek is lined with a narrow band of mature trees. There are areas where all bank vegetation as been removed, such as at the Hendersonville wastewater treatment plant site and at powerline crossings. Banks are sometimes unstable, and blowouts occur where trees have fallen into the creek. There are several sites where cattle have access to the creek, decreasing stream bank stability.

In-stream habitat

Sand/silt is the dominant substrate throughout lower Mud Creek. There are rare gravel/cobble riffles and a few bedrock shoals, which provide gradient control. Within Hendersonville, there is a considerable amount of junk in-stream, including concrete blocks and machine parts.

Because larger trees line the stream banks, large woody debris and edge habitat (undercut banks, roots) are present. Smaller organic microhabitat, such as sticks and leafpacks, is somewhat limited. Channelization and limited riparian vegetation have decreased in-stream roughness, decreasing the stream's ability to catch organic microhabitats.

Sediment and nutrient sources

Eroding stream banks in lower Mud Creek are major sources of sediment, especially in blow out areas. Upland areas cleared for development also contribute sediment to Mud Creek. Mud Creek tributaries, large (e.g., Clear Creek) and small (e.g., stormwater ditches), contribute considerable amounts of sediment from eroding banks and upland areas.

Obvious nutrient sources are cattle that have access to Mud Creek and some of its tributaries. In addition, the Hendersonville WWTP, residential and agricultural fertilizer, leaking septic systems, and straight pipes contribute nutrients to lower Mud Creek.

Tributaries

Urban tributaries such as Wash Creek are often very unstable and incised, bordered by limited to no riparian vegetation. Many of these tributaries were likely channelized and the banks built up to prevent flooding of the surrounding land. These tributaries serve as the stormwater network of Hendersonville, receiving very high scouring flows during storm events.

Downstream of Hendersonville, larger tributaries such as Featherstone Creek have headwaters in forested land, and are more stable systems. As they approach the wide Mud Creek floodplain, however, they have often been channelized and in-stream habitat is limited.

7.6 Conclusions: Identification of Causes and Sources of Impairment

Impacted biological communities were noted throughout lower Mud Creek during the present study. Lower Mud Creek integrates the impacts from each of the Clear Creek, Devils Fork, Bat Fork, and upper Mud Creek subwatersheds. Impaired benthic communities were documented in all of these contributing subwatersheds, and many stressors documented in these areas exist in lower Mud Creek as well. Each stressor investigated during this study is evaluated below. See Section 3.5.1 for definitions of stressor types (e.g., cumulative cause of impairment).

7.6.1 Habitat Degradation Due to Sedimentation

> Sedimentation is a cumulative cause of impairment.

Excess sediment deposition was evident throughout lower Mud Creek, with sand and silt comprising almost all of the bottom substrate. Riffles are an important type of in-stream habitat, supporting a diversity of benthic macroinvertebrate taxa, including many EPT species. Very few natural riffles were present, and any found were highly embedded, reducing their quality as benthic habitat. *Sedimentation is considered a cumulative cause of impairment for lower Mud Creek.*

<u>Sediment sources.</u> Sources of sediment are numerous and come from both in-stream and upland sources throughout Mud Creek's 113 mi^2 watershed. Unstable and unvegetated banks of both lower Mud Creek and its tributaries are an important source of sediment. Mud Creek and many of its tributaries are incised and laterally unstable. These creeks have likely downcut to lower bed levels. Much of lower Mud Creek and its tributaries have been channelized, which is often accompanied by incision. The practice of clearing bank vegetation further destabilizes stream banks. Exposed loose soil erodes into streams during storm events, increasing suspended and bed load sediments. In addition, cattle have access to lower Mud Creek and some of its tributaries, and this causes banks to collapse and contribute sediment to these streams.

Upland sources of sediments are important in this watershed as well. Land disturbance for commercial and residential development and unpaved roads and driveways provide sources of sediment.

7.6.2 Habitat Degradation--Other Issues

> Lack of a diversity of depth and velocity combinations (riffles, pools, bends) is a cumulative cause of impairment.

As in upper Mud Creek and Bat Fork, other watershed-wide issues contribute to habitat degradation in lower Mud Creek. Extensive channelization over the past 150 years has led to channel "simplification"—a straighter channel with few bends, riffles, and pools. Conversely, meandering channels generally have a diversity of depth and velocity types, providing key habitats for aquatic organisms. Within a meandering channel, this diversity of depth and velocity provides channel roughness, or irregularity, that is important in catching organic microhabitats, such as sticks and leaves. In areas where the stream channel did meander below stream bank blowouts, there were a variety of depth and velocity combinations.

This habitat issue likely acts in concert with sedimentation to impact the aquatic community. *Lack of suitable in-stream habitat, namely a diversity of depth and velocity combinations (riffles, pools, bends), is considered a cumulative cause of impairment.*

7.6.3 Toxicants

> Based on watershed-wide evidence of toxicity, exposure to toxicants, likely pesticides and urban pollutants, is a cumulative cause of impairment for lower Mud Creek.

Benthic community analysis provides some evidence that toxicants impact the benthic community of lower Mud Creek. The benthic community throughout lower Mud Creek demonstrated typical characteristics of toxic stress—toxicant-intolerant taxa, such as stoneflies, were absent and more tolerant taxa were dominant. The benthic community at 7th Ave. in Hendersonville fluctuated over time, on the same cycle of stress and recovery noted in upper Mud Creek where toxic impacts were apparent.

Although sediment, SPMD, and water column analyses documented the presence of contaminants, limited chemistry data from the lower Mud Creek subwatershed did not provide evidence of toxicity. However, acute toxicity was documented in an adjacent urban stream, Devils Fork, and the potential for toxic impacts in the urban area of lower Mud Creek is great. In addition, lower Mud Creek receives the flows from Clear Creek, upper Mud Creek, and Devils Fork, all of which likely suffer from toxic exposure.

In the lower Mud Creek mainstem, sediment and SPMD analysis provides evidence of organochlorine pesticides, PCBs, and semi-volatile organic contaminants, but water chemistry analysis indicated no problematic metal or organic contaminant levels. Stormflow sampling was very limited, and it is difficult to characterize storm water chemistry well. However, tributary sampling provides evidence of toxicants. No non-pesticide organic contaminants were measured at concentrations above water quality benchmarks, but high metal levels were common in stormflows. Copper, lead, and zinc concentrations above published benchmarks were observed in urban tributaries (i.e., tributary to Mud Creek at Green Meadows Park, Johnson Drainage Ditch, Devils Fork) during stormflows. Water column bioassays performed on these stormflows indicated the presence of toxicity in one Devils Fork stormflow; extremely high copper, lead, and zinc levels were measured in this sample.

Toxic impacts, especially if caused by storm inputs, can be very episodic and difficult to identify. One cannot rule out toxicity due to the occurrence of spills or infrequent incidents that occurred between sampling events. Additionally, determining how laboratory bioassays apply to the in-stream context is sometimes not straightforward. While laboratory bioassays are very useful in integrating the impacts of multiple pollutants (accounting for cumulative effects), laboratory conditions often will not reflect actual in-stream exposures (or other conditions) or account for the full range of biological responses (Burton and Pitt, 2001; Herricks, 2002). For example, stream organisms may experience multiple stresses over an extended period of time (such as repeated pulse exposures to various pollutants), a situation difficult to duplicate in laboratory bioassays. While difficult to assess, the long-term cumulative effects of frequent exposures is likely important (Burton and Pitt, 2001). Also, volatile toxicants can escape from a sample and result in toxicity test conditions that are not representative of in-stream toxicant levels.

Exposure to toxicants is the primary cause of impairment in Clear Creek and a key issue in upper Mud Creek; pesticides were identified as the most likely toxicants in these streams (see Sections 4.6 and 6.6 for discussion). Water and sediment from these areas eventually flow into lower Mud Creek; toxicants in water and attached to sediments enter lower Mud Creek as well. However, it is unknown if these pesticides occur at concentrations high enough to cause toxicity in lower Mud Creek.

There are seven wastewater treatment plants (WWTPs) in the subwatershed, but most have limited potential to influence the Mud Creek mainstem due to their size and location. Of note is a set of three WWTPs on a small tributary to Featherstone Creek (Brookside Village Association, Hendersons Rest Home, and Mountain View Assisted Living), which are responsible for elevated levels of in-stream chlorine; these levels may impact the benthic community in this tributary and perhaps Featherstone Creek, but are likely quite low in Mud Creek due to dilution. The Hendersonville WWTP had a number of Notices of Violation in 2000-2001, but benthic sampling performed directly above and below shows little change in benthic community.

Based on analysis of benthic macroinvertebrate data and chemical data from throughout the Mud Creek watershed, exposure to toxicants is considered a cumulative cause of impairment for lower Mud Creek. The available data cannot pinpoint specific toxicants, but based on an analysis of potential sources, pesticides and urban pollutants are likely.

7.6.4 Stormflow Scour

> Stormflow scour is a cumulative cause of impairment for Mud Creek below Hendersonville.

Observation during storms indicated that water levels and velocities of both urban sections of Mud Creek and its urban tributaries changed rapidly during the onset of storm events. These high velocity flows cause considerable movement of bed substrate and microhabitat, such as leafpacks and sticks. Aquatic organisms can also become dislodged with high energy stormflows, especially where there is little channel roughness providing refuge from scour. Due to the incised nature of these stream channels, the energy of the streams is confined within the banks except during large storms.

The urban areas of Hendersonville and Laurel Park are highly impervious (see Section 2.42), and 20-50% of some drainage areas are covered by impervious surfaces. Seventeen percent of the lower Mud Creek subwatershed is impervious. In addition, many pervious areas have been highly modified and have lost some infiltration capacity. Most development predates current stormwater control requirements. Significant hydrologic impacts can generally be expected under these conditions.

Taken as a whole, these observations strongly suggest scouring of substrate occurs frequently, and likely contributes to both habitat degradation and dislodging of organisms. While difficult to isolate from other factors associated with a developed watershed, this is very likely an important and pervasive stressor that contributes to impairment of the macroinvertebrate community.

Stormflow scour is considered a cumulative cause of impairment for Mud Creek below Hendersonville.

7.6.5 Other Possible Stressors

The extended drought that began mid-1998 decreased flows in the Mud Creek watershed, and may serve as an additional stressor to aquatic invertebrate communities (see Section 4.6.4). However, it is unlikely that low flows are a key stressor; reference sites in the adjacent Crab Creek watershed sampled during the same period (see Sections 5.3 and 6.3) were rated Good or Excellent.

Water chemistry data provide evidence of high nutrient levels in lower Mud Creek, and possible sources of nutrients include the Hendersonville WWTP, fertilizer from residential and agricultural areas, cattle allowed in Mud Creek and its tributaries, straight pipes, and leaking septic systems. The fish community sampled in 2002 was impacted by excessive nutrients. However, benthic community analysis did not indicate problems with nutrient enrichment, so nutrients are not considered a stressor for lower Mud Creek.

> Lack of upstream colonization sources is a cumulative cause of impairment.

Degradation of tributaries also impacts lower Mud Creek. Due to their role as colonization sources, tributaries are important in maintaining mainstem benthic populations. Benthic populations are dynamic. Taxa can be lost through catastrophic events, such as stormflow scour, drought, and toxicants. Recolonization after catastrophic events occurs through a number of mechanisms, with downstream drift considered the most important method of colonization (Smock, 1996). Thus, a stream benthic macroinvertebrate community is the sum of its watershed; if upstream sources are impacted, then the maintenance of a healthy stream community is limited. Large tributaries, such as Bat Fork, Devils Fork, and Clear Creek, are characterized by severely impacted benthic communities. Small tributaries in the lower Mud Creek subwatershed generally have poor habitat near their confluences with Mud Creek; they are very incised and often channelized streams. *Lack of upstream colonization sources is considered a cumulative cause of impairment.*

7.6.6 Conclusion

A primary cause of impairment was not identified for lower Mud Creek and may not exist. However, the available data point to the cumulative impacts of a number of stressors. Toxicants, habitat degradation due to sedimentation and a low diversity of depth and velocity combinations (riffles, pools, bends), scour from stormflows, and the lack of upstream colonization sources are considered cumulative causes of impairment.

Section 8
Improving Stream Integrity in the Mud Creek Watershed: Recommended Strategies

As discussed in previous sections, there are a number of stressors acting in concert that impact Clear Creek, Devils Fork, Bat Fork, and Mud Creek (Table 8.1). Toxicity from pesticides and urban sources, stormflow scour, and a number of habitat degradation issues—including sedimentation, a lack of riffles, pools, and bends, and a lack of organic microhabitat—are all causes of impairment for one or more streams in the Mud Creek watershed. In addition, watershed-wide degradation is manifested in the lack of upstream colonization sources for biological communities. Nutrient enrichment is not a cause of impairment, but contributes to biological degradation in Clear Creek and Devils Fork. This section discusses how these problems can be addressed. A summary of recommendations is included at the end of the section.

Table 8.1 Stressors Identified in the Mud Creek Watershed[1]

Stressor	Clear Creek	Upper Devils Fork	Lower Devils Fork	Bat Fork	Upper Mud Creek	Lower Mud Creek
Pollutants						
Pesticides	P	P	C		P	C
Urban toxicants/metals	?		C			C
Unknown toxicants				C		
Nutrient enrichment	CS	CS	CS			
Habitat degradation						
Sedimentation	CS	CS	C	C	C	C
Lack of riffles, pools, and bends			C	C	C	C
Lack of organic microhabitat			C	C	C	
Other stressors						
Stormflow scour			C			C
Lack of upstream colonization sources				C		C

1 See Section 3.5 for a description of terms.
P = primary cause of impairment
C = cumulative cause of impairment
CS = contributing stressor
? = potential cause or contributor

8.1 Addressing Current Causes of Impairment

The objective of stream quality improvement efforts is to restore water quality and habitat conditions to support a diverse and functional biological community. In some areas, especially in Clear Creek, Devils Fork, and upper Mud Creek, significant improvements in stream integrity are possible. Because of the widespread nature of biological degradation and the highly developed character in lower parts of the watershed, bringing about substantial water and habitat quality improvement will be a tremendous challenge in these areas. Yet the watershed has not been so highly modified as to preclude improvements in stream integrity. A return to the relatively unimpacted conditions that existed prior to widespread agriculture and urbanization is not possible, but the Mud Creek watershed can potentially support a healthier biological community than it does today.

In some stream sections, particularly lower Mud Creek and Bat Fork, the interrelationship of key factors causing impairment is unclear. Additionally, there are inherent uncertainties regarding how individual best management practices (BMPs) cumulatively impact receiving water chemistry, geomorphology, and habitat (Shields et al., 1999; Urbonas, 2002), and in how aquatic organisms will respond to improved conditions. For these reasons, the intensity of management action necessary to bring about a particular degree of biological improvement cannot be established in advance. This section describes the types of actions needed to improve biological conditions in the Mud Creek watershed, but the mix of activities that will be necessary –and the extent of improvement that will be attainable– will only become apparent over time as an adaptive management approach is implemented (see Section 8.3). Management actions are suggested below to address individual problems, but many of these actions are interrelated (e.g., particular BMPs or systems of BMPs can be designed to serve multiple functions).

8.1.1 Pesticides

While some aspects of pesticide usage on apples and row crops are known, which mechanisms are most important in stream delivery are unclear. DWQ will work with NC Department of Agriculture and Consumer Services, NC Division of Soil and Water, and other agencies to better understand pesticide use, delivery mechanisms, and potential solutions. Based on DWQ's current understanding of pesticide impacts, the following strategies are suggested.

<u>Tomato/pepper pesticides</u>
Tomato/pepper fields occur throughout the watershed, but are prominent along upper Mud Creek, where they are the most likely source of toxic impacts. There are a number of pesticides used that are highly toxic to aquatic invertebrates. Most pesticides are sprayed directly on the tomatoes/peppers with a direct nozzle or airblast sprayer. There is some potential for groundwater leaching of tomato/pepper pesticides. All of the seven more commonly used pesticides listed in Section 2.5.2 are considered insoluable in water, but the additional organophosphate, carbamate, and chloro-nicotinyl insecticides listed are moderately to highly soluable in water.

Aside from groundwater leaching, there are four main possible mechanisms for stream delivery from these fields:

1) *Spills in pesticide mixing areas*. Many pesticide mixing areas are adjacent to streams, increasing the potential for pesticide delivery to streams. Agrichemical mixing facilities have been designed to minimize pesticide contamination, and there is currently a Henderson County cost-share program to provide these facilities to apple growers. These facilities are expensive ($20,000/facility). Since there are many small tomato/pepper fields in the watershed, a less expensive system should be developed. Ideally, this system should (a) be

placed at an adequate distance from the stream and (b) capture spilled chemicals. Farmers should employ good housekeeping (e.g., adhering to pesticide label specifications and disposing of pesticide containers in a proper place).

2) *Stormwater runoff*. Many tomato/pepper fields are in floodplain areas and have little if any woody vegetation along the stream edge. Some fields are bermed at the stream edge, but breaks in berms are common; stormwater is funneled through these breaks or through ditches dug into the fields (Figure 8.1). The use of riparian vegetation could reduce the pesticide contamination of streams in the watershed. Pesticides can be broken down within buffer soils, and a buffer's effectiveness increases with buffer width (Wenger, 1999). The success of riparian vegetation is limited in removing pollutants if field runoff is concentrated through a ditch or berm break; runoff should be evenly spread through riparian vegetation. The Henderson County Soil and Water Conservation District (SWCD) and NC Cooperative Extension Service should work with landowners to plant effective buffers and control stormwater runoff so that flow is dispersed through buffers rather than concentrated in channels.

3) *Backflow siphoning*. Drip irrigation systems are occasionally used to deliver pesticides to tomatoes/peppers, and backflow siphoning of contaminants is a potential problem (see Section 2.5.2). These systems should be retrofitted with a dependable backflow prevention system. Current state pesticide rules require an effective backflow prevention system for chemigation systems. A program via NC Agriculture Cost Share is currently in place to retrofit these systems, but there is little interest by area farmers in using this program. Farmers should be required by NC Department of Agriculture and Consumer Services to retrofit their drip irrigation systems to eliminate the possibility of direct pesticide contamination of streams.

4) *Filter backwash.* When drip irrigation systems are used as chemigation systems to deliver pesticides, filters are backwashed during the irrigation cycle, sometimes directly to the water source. Filter water can carry pesticides, fertilizers, and other substances. Farmers should be educated to reuse filter water or release it away from surface waters. In addition, farmers should be encouraged to place pesticide injection points on the outlet side of all media filters.

<u>Pesticides from other row crops</u>

Although not investigated by this study, row crops other than tomatoes and peppers are grown throughout the watershed. Other crops are grown with drip irrigation methods, including squash and eggplant. Corn is a widespread crop, as well. Where adjacent to streams, these fields often have no or a limited vegetated buffer and/or a pesticide mixing station near the stream. Farmers should be encouraged to plant riparian vegetation to remove pesticides from storm runoff and establish a pesticide mixing area that is away from the stream and controls spills.

Impacts from past-use pesticides used on row crops may also be important, especially in the Clear Creek subwatershed. Control of sediments on fields and on eroding stream banks is important to reduce the likelihood of these pesticides reaching streams.

Figure 8.1 Berm break in tomato field.

Figure 8.2 Apple orchard near stream.

Apple pesticides

Both past and current use pesticides are present in streams draining apple growing areas, which are primarily in Clear Creek, Devils Fork, and Dunn Creek drainages. The available data provide evidence that at least one pesticide currently used on apples and row crops, esfenvalerate, was at concentrations high enough to impact the benthic macroinvertebrate community, although its bioavailability was unknown. Since many current use pesticides could not be analyzed due to limitations of analytical methods, other pesticides may also play a role in benthic community degradation. Although organochlorine pesticides no longer registered for sale were found in sediments that failed chronic toxicity bioassays, the role of these pesticides in observed benthic community impacts is unclear. In addition, the role of contaminated sediments in benthic community impairment is unknown.

Apple growers have taken many steps to reduce the likelihood of pesticide contamination of streams. There has been a general move from organophosphate insecticides, and some farmers are also shifting away from broad spectrum pyrethroids. There is a much higher awareness of proper pesticide handling and mixing procedures, and most farmers have planted buffers between irrigation ponds and streams and installed backflow preventors on irrigation pumps. In addition, many farmers are active in an Integrated Pest Management program. The following strategies are suggested to further mitigate pesticide impacts from apple orchard pesticides:

1) *Agrichemical mixing facilities*. As noted for tomato/pepper fields, many pesticide mixing areas are near streams and are possible sources of stream contamination. NC Agricultural Cost Share Program funds are available for apple growers, but these facilities are expensive and Henderson County can currently only fund two or three of these facilities per year. There is currently a waiting list of farmers interested in acquiring Cost Share funds to build these facilities. More funds should be made available to meet farmers' needs.

2) *Stream-side riparian vegetation*. Apple orchards that are along streams often have limited riparian vegetation (Figure 8.2). According to IPSI data, only 11% of the perennial stream

miles in the Clear Creek watershed have adequate buffers. Buffers can reduce pesticide delivery to streams from both spray drift and storm runoff (Wenger, 1999). The Henderson County Soil and Water Conservation District should work with landowners to plant riparian vegetation.

3) *Integrated Pest Management (IPM).* Many apple farmers in the Mud Creek watershed currently use scouts to monitor the need for pesticide application, and approximately 40% of the apple orchard land is under IPM. By applying pesticides only when recommended by the scouts rather than on a predetermined schedule, farmers use 30% less pesticides [Bob Carter, Natural Resources Conservation Service (NRCS), personal communication]. This practice costs approximately $30/acre and is approved for NC Agricultural Cost Share Program funds. More funds should be made available to allow all growers involvement in the IPM program.

4) *Removal of abandoned apple orchards*. Although Henderson County has a long apple growing tradition, many growers are abandoning their orchards for more profitable ventures. Abandoned orchards are a breeding ground for pests that can migrate to adjacent orchards, requiring growers to apply more pesticides. Removal of abandoned orchards costs $400/acre (Bob Carter, NRCS, personal communication). There are approximately 1,000 acres of abandoned orchards in the Mud Creek watershed. Henderson County SWCD should work with landowners to remove all abandoned orchards. In order to insure that sediments that may contain past-use pesticides stay on site, proper sediment and erosion control is essential.

5) *Minimize spray drift.* Henderson County SWCD and NC Division of Soil and Water Conservation should develop new NC Agricultural Cost Share Program funded practices to minimize pesticide drift. Henderson County is a leader in developing Cost Share practices to address pesticide management. The County should explore new technologies, such as charged sprayers, that growers can use to reduce pesticide drift.

6) *Stabilize eroding stream banks*. Eroding stream banks in current or old apple orchards may provide a continuing source of sediments contaminated with organochlorine pesticides. IPSI data indicate that there are over 30,000 feet of eroding stream banks adjacent to active and abandoned orchards concentrated in the Clear Creek and Devils Fork subwatersheds, and field reconnaissance indicates that this is likely an underestimate. The Henderson County SWCD should work with landowners to stabilize streams near orchards to minimize the transport of historic pesticides.

7) *Encourage organic apple farming*. The ultimate answer to limiting pesticide impacts is to grow apples in a way that poses no risk of pesticide contamination. The Cooperative Extension Service and the Appalachian Sustainable Agriculture Project have assisted three apple growers in Henderson County to convert to organic growing methods. 2002 field trials in Henderson County have proven that organic apple growing can be viable (Marvin Owings, NC Cooperative Extension, personal communication). Organic apple farming is much more expensive per acre than traditional apple farming. Since federal law on organic agriculture requires three years of organic growing before a farm can be certified "organic", a transitioning farmer cannot market his/her apples as organic and this can prove to be a considerable economic hardship. More funds to enable farmers to transition to organic methods should be developed.

8) *Determine the role and sources of past-use pesticides in benthic impairment*. Further baseflow monitoring of organochlorine pesticides no longer registered for sale should be performed to determine the possible role of these contaminants in benthic community impairment. To determine the sources of these pesticides, soils in current and former apple orchard areas should be analyzed for pesticides and the possibility of contaminated groundwater feeding streams during baseflow periods should be investigated.

9) *Further determine delivery pesticide mechanisms*. Further monitoring should be performed to determine the role of various mechanisms of pesticide delivery to streams. The current DWQ study has demonstrated that storms carry high levels of some current use pesticides, and this is likely from field runoff. However, the current study cannot pinpoint a definite source of these pesticides, which are used on both apples and row crops. In addition, the role of spills and spray drift has not been determined, and further monitoring could be used to determine the role of these mechanisms in stream impairment.

<u>Pesticides from non-agricultural sources</u>
Intensive users of pesticides, such as golf courses and landscapers, should be encouraged to use compounds that pose less of a risk to water quality and limit their use around surface waters. Area golf courses should diligently implement management practices to lessen the impacts of pesticides and fertilizers on surface waters (e.g., integrated pest management, untreated buffer zones along waterways).

8.1.2 Stormflow Scour

Frequent periods of high-velocity stormflow dislodge benthic organisms and contribute to habitat degradation by removing organic microhabitat and causing bank instability. This will continue to be problem for urban streams in the watershed (lower Mud Creek, Johnson Drainage Ditch, lower Devils Fork, Wash Creek, Brittain Creek) unless some of the hydrologic impacts of existing development can be abated. The vast majority of development occurred prior to any BMP requirements. Stormwater controls are necessary to partially restore watershed hydrology by reducing runoff volume and reducing the frequency and duration of erosive flows.

Stormwater retrofits are structural stormwater measures (BMPs) for urban watersheds intended to lessen accelerated channel erosion, promote conditions for improved aquatic habitat and reduce pollutant loads (Claytor, 1999). A range of practices, including a variety of ponds and infiltration approaches, may be appropriate depending on specific local needs and conditions. Practices installed to reduce hydrologic impacts will also provide varying degrees of pollutant removal.

<u>Stormwater retrofit options</u>. Available structural and nonstructural retrofit practices to reduce hydrologic impacts and remove pollutants have been discussed widely in the literature (e.g., ASCE, 2001; Horner et al., 1994) and detailed in state BMP manuals (e.g., NCDWQ, 1999; Maryland Department of the Environment, 2000). Some of these include:

- detention ponds;
- retention ponds;

- stormwater wetlands;
- bioretention;
- infiltration structures (porous pavement, infiltration trenches and basins);
- vegetative practices to promote infiltration (swales, filter strips);
- 'run on' approaches (regrading) to promote infiltration;
- reducing hydrologic connectivity (e.g., redirecting of downspouts);
- education to promote hydrologic awareness; and
- changes in design/construction standards.

Determining which BMPs will be most feasible and effective for a particular catchment depends on numerous site specific and jurisdictional specific issues. These issues include drainage patterns, size of potential BMP locations, treatment volume needed considering catchment size and imperviousness, soils, location of existing infrastructure, and other goals (e.g., flood control, water quality). Considerations in the identification of retrofit sites are discussed by Schueler et al. (1991) and Claytor (1999). A key design challenge is to maximize hydrologic mitigation and/or pollution removal potential while limiting impacts to infrastructure and existing structures.

DWQ encourages the consideration of a wide range of practices and approaches. Ponds of various types are probably the practice most familiar to engineers and can indeed be versatile and cost-effective. Detention alone does not reduce stormwater volume, however, though the rate and timing of discharge can be controlled. It is important to carefully examine infiltration practices, including both structures and 'behavioral' changes such as redirecting downspouts to pervious areas. While there are clearly limits to the usefulness of infiltration, based on soils, water table levels and other factors (Livingston, 2000) these practices are often underused. Design approaches to minimize runoff volume are also important tools (Caraco et al., 1998; Prince George's County DEP, 2000). Some retrofit methods may have negative side effects that must be carefully considered. For example, regional wet detention facilities, though they may remain a viable alternative in some situations, can disrupt recolonization, alter the food/energy source available to downstream biota, and, depending upon design and operation, reduce or eliminate downstream baseflows (Maxted and Shaver, 1999; Schueler, 2000b).

<u>Recommendation</u>. What is feasible or cost-effective in the way of retrofitting a developed watershed like the urban areas of the lower Mud Creek, Devils Fork, and Bat Fork subwatersheds is constrained by existing conditions. Conditions change, however, and a long-term commitment to partially restoring watershed hydrology will be necessary to create opportunities and take advantage of the available options. In order to have a biologically meaningful impact on watershed hydrology, cost-effective projects will likely have to be sought out and implemented over an extended time frame.

1. Short-term. Over the next decade, the towns of Hendersonville, Laurel Park, and Flat Rock can investigate retrofit possibilities and implement those that are feasible given current infrastructure and financial constraints.
2. Mid-term. Road realignment, sewer line and bridge replacement and other infrastructure projects will likely make feasible other retrofit opportunities over the next 10-20 years. Such projects can be pursued and the search for retrofit opportunities can be integrated into the capital improvement planning process.

3. Long-term. Over a more extended period, cost-effective restoration opportunities are likely as portions of the watershed are redeveloped incrementally (Ferguson et al., 1999). An ongoing awareness of retrofit needs and changes in development regulations may be necessary to help create and take advantage of these opportunities.

These efforts should be prioritized in the most impervious areas of the watershed, including the drainages of Wash Creek and Brittain Creek and the urbanized portions of Devils Fork, Bat Fork/Johnson Drainage Ditch, and Mud Creek.

<u>Costs</u>. Stormwater retrofit costs are difficult to estimate until specific practices and locations have been selected. Unit costs vary greatly with the size of the area treated. Using data from the mid 1990s, Schueler (2000c) reported that typical costs for stormwater ponds were about $5,000 per impervious acre treated for projects covering 100 impervious acres but $10,000 per impervious acre treated for projects treating 10 impervious acres. Treating a single acre cost an average of $25,000 or more.

Only gross estimates of total costs are possible. Claytor (1999) suggests that a minimum of 50% of a watershed be retrofitted. Thus, for example, a two square mile watershed that is 25% impervious has approximately 320 impervious acres (2 square miles, or 1280 acres, times an imperviousness of 25%). Assuming a typical cost of $10,000 per impervious acre, it would take approximately $1.6 million to retrofit 160 impervious acres. This approaches $1 million per square mile of total watershed area. This estimate should be used only as a general indication of the likely scale of effort that may be necessary, assuming a sufficient number of viable retrofit projects can be identified. Actual total costs may be higher or lower depending on many factors, including the types of BMPs used and the scale of each project. Some cost reduction may be possible if retrofits are planned and implemented in conjunction with anticipated capital improvements and infrastructure enhancements. The potential connection between watershed restoration and infrastructure issues has been increasingly recognized by local governments (e.g., City of Austin, 2001; Montgomery County DEP, 2001).

8.1.3 Urban Toxicants

While high levels of some urban contaminants have been found, the particular pollutants or mix of pollutants of primary concern remains unclear. Long-term impacts of repeated exposures may be important, and the most critical toxicants may vary with time, associated with specific events. Source areas likely lie throughout the watershed, but the greatest concentration of these are in the highly urbanized areas of Hendersonville and Laurel Park and their outskirts.

Two broad approaches can be used to address toxic impacts: structural BMPs to remove pollutants from stormwater and primarily nonstructural source reduction methods to prevent pollution inputs (NVPDC, 1996; Heaney et al., 1999). These approaches are not mutually exclusive and a multifaceted strategy drawing on both approaches will be more effective than a more narrowly focused effort. A general conceptual strategy to address toxicity from urban contaminants is outlined below. This should be viewed only as an initial framework for planning and implementing toxicity reduction efforts. Ongoing planning and strategy reassessment will be necessary to refine the scope and nature of management efforts.

1. Implementation of available BMP opportunities for control of stormwater volume and velocities. Recommended earlier in order to reduce scour impacts and improve aquatic habitat potential, these BMPs will also remove toxicants from the stormwater system (the extent of removal will vary depending upon the specific structures and pollutants involved).

2. Development of a stormwater and dry weather sampling strategy for the urban part of the watershed. A wide range of conventional BMPs can be used to remove pollutants from stormwater runoff (see ASCE, 2001). For example constructed wetlands, vegetated swales, and various types of ponds can remove a substantial percentage of metals. Selection of particular BMPs can proceed more efficiently, however, if better information on specific target pollutants and source areas is available. Such information would also aid in the targeting of source reduction efforts (discussed below). To address these needs, a monitoring strategy should be developed based upon further watershed reconnaissance.

3. Implementation of stormwater treatment BMPs, aimed primarily at pollutant removal, at appropriate locations. Results of additional monitoring will be important in targeting these BMPs, although some likely "hot spots" (areas of intense activity or high risk) could be identified without water quality sampling. Proprietary treatment systems can be considered where adequate space is not available for conventional stormwater BMPs.

4. Development and implementation of a broad set of source reduction activities. Since removing pollutants from stormwater can be difficult and expensive, pollution prevention activities are crucial. Among activities that should be considered for inclusion in pollution prevention efforts are:

- Reducing non-storm inputs of toxicants by:
  a) identification and elimination of illicit connections (actions required under phase II stormwater regulations);
  b) review of existing information on groundwater contamination and implementation of appropriate remediation measures if warranted;
  c) verification that industrial and commercial floor drains empty to the sanitary sewer system or appropriate treatment facilities; and
  d) education of homeowners and industrial and commercial operation and maintenance staff regarding proper use of storm drains and the implications of dumping.

- Reducing pollutants available for wash off during storms by:
  a) education of homeowners, grounds staff, and commercial applicators regarding appropriate pesticide use;
  b) provision of technical assistance to golf course and city park staff regarding appropriate pesticide use.
  c) outreach and technical assistance to industrial and commercial facilities regarding materials storage practices; spill prevention procedures; and spill control and cleanup procedures.

- Managing water to reduce storm runoff by:
  a) routing roof drains and pavement to available pervious areas where feasible (may require some regrading);

b) installing rain gardens; and
c) proper maintenance of existing BMPs.

Development of a specific pollution prevention strategy is beyond the scope of this study. Some elements of a strategy could probably be implemented by enhancing or redirecting existing program activities. In other cases new initiatives may be necessary. While state agencies such as DWQ and the Division of Pollution Prevention and Environmental Assistance can play a role, planning and implementation of a strategy is likely to be more effective if carried out by local government, agencies and stakeholders.

The condition of residential lawns and commercial grounds in this watershed strongly suggests that turf chemicals are likely applied in substantial quantities. Education for property owners, maintenance staff of commercial facilities and commercial applicators regarding pesticide use should be a priority. While clear pesticide impacts associated with golf courses were not documented during the study, the location of these facilities along waterways increases the risk of periodic impacts if proper procedures are not followed. A review of chemical handling and application practices would be appropriate.

Addressing vehicle related pollution will be a particular challenge. BMPs to treat parking lot runoff may often be feasible, but addressing roadway runoff will be more difficult. Source control may have to wait for changes in vehicle or component design (e.g., changes in brake pad composition).

High total residual chlorine (TRC) levels were measured in a tributary to Featherstone Creek where three small WWTPs discharge waste. In the past, some WWTPs with no TRC permit limits have reported levels of up to 1000 µg/L in their discharge. In order to address this problem, in July 2002 DWQ began to require WWTPs to monitor TRC to the lowest level possible. Major WWTPs (Hendersonville WWTP) can be fined for levels $\geq$50 µg/L for the first year, and minor WWTPs (all other WWTPs) can be fined for levels $\geq$100 µg/L for the first 18 months. After the first year of monitoring, DWQ will examine TRC monitoring methods and develop a set of guidelines.

8.1.4 Habitat Degradation

Habitat degradation—namely sedimentation, lack of organic microhabitat, and/or lack of pools, riffles, and bends—is a systemic issue in the Mud Creek watershed. It is most severe in streams that have low gradient and have been extensively channelized. It is a cause of impairment for Bat Fork, lower Devils Fork, and Mud Creek. Although excess sedimentation is a low-level stressor for upper Devils Fork and Clear Creek, habitat degradation is not a driving factor in impairment due to several factors—the higher gradient of the systems transports fine sediments through the streams, the creeks have somewhat more natural meander, and there is often a wooded buffer (although sometimes thin) that provides edge habitat, some bank stability, and organic microhabitat inputs. Habitat degradation is likely a greater issue for some lower gradient and channelized tributaries of Clear Creek that were not the focus of this study, such as Lewis and Henderson Creeks.

In order to solve the chronic problems of habitat degradation in Mud Creek, Bat Fork, and lower Devils Fork, a large-scale restoration plan is needed. Excess sedimentation and a lack of pools, riffles, and bends are consequences of channelization. These streams are often incised and unstable, contributing a large amount of sediment to the streams. If no large-scale action is taken to stabilize these creeks, they will widen until they have created a stable channel configuration within their current incised channels. This will occur once these streams are wide enough to allow for the natural dynamic processes of meandering and flooding. This process may take many decades, and as it occurs, stream banks will contribute in-stream sediment as the channel widens. Habitat degradation will continue to be a major stressor for aquatic communities, landowners will lose property, and this watershed will serve as a continued source of sediment to the French Broad River. Improving habitat in these streams will ultimately require a set of strategies that addresses stream habitat on a watershed-wide level.

1) <u>Restoration of Mainstem Streams</u>
   The alternative to waiting decades or longer for these low gradient streams to stabilize themselves is to restore stable profile, pattern, and dimension (restoration of sinuosity, width and depth to a relatively stable state) and an adequate wooded buffer to these creeks. This would be a large undertaking, involving many landowners and much expense. These streams can be divided into three types, with different constraints:

   a) *Bat Fork and upper Mud Creek.* These rural streams have been channelized and are very incised. They are likely the easiest to restore due to their small size and rural nature. The best option for stream restoration is to reconnect the channel with its original floodplain, recreating a meandering channel (Rosgen priority 1 approach). This requires the most space of any restoration approach, and a more feasible approach in some areas is to construct appropriate floodplain area and channel form within the existing incised channel (Rosgen priority 2 or priority 3 approach). The specific restoration strategy selected will depend upon the stream corridor width available (belt width), among other factors (NCSU, 2001a; Rosgen, 1997). Buffer vegetation would be established as part of any restoration approach. Using the upper estimation of cost for either priority by NC State University (2001a) of $117 per foot, this work would cost about 4 million dollars for Bat Fork (entire length to Johnson Drainage Ditch, 6.4 mi) and 4.5 million dollars for upper Mud Creek (between the lake at Camp Blue Star and Erkwood Rd., 7.2 mi).

      If large-scale restoration is not implemented, actions should be taken to facilitate the ability of these streams to improve naturally. Two important factors are to encourage the planting of woody riparian vegetation and to discourage the use of hard stabilization measures. Landowners should be encouraged to replant a buffer (at least 30 ft wide) of native woody vegetation along stream banks and allow the streams to slowly readjust to some stable configuration. This woody buffer will provide a source of organic microhabitat and eventually some roughness in the channel. Natural processes will allow these creeks to heal themselves eventually, but the issues of a lack of pools, riffles, and bends and sedimentation due to bank erosion will persist for many years and may worsen before these streams stabilize. Landowners have attempted to stabilize banks by armoring them in place with tires, wood, cars, concrete, and other materials; this is likely to continue.

While this may stabilize local areas of the bank in the short-term, it hinders and prolongs the process of stream adjustment and eventual stabilization.

If large scale restoration is not undertaken, it would be useful to restore limited stretches of the creeks that most are actively eroding and contributing large amounts of sediment, especially those areas that have cattle access (one site on upper Bat Fork and another on upper Mud Creek). Cattle should be excluded from these streams and alternative water sources provided.

b) *Lower Devils Fork (I-26 area to confluence with Johnson Drainage Ditch), Johnson Drainage Ditch, and urban sections of Mud Creek.* These streams are wide, straight channels due to extensive channelization and receive large amounts of stormwater from the Hendersonville area. They are sometimes constrained by roads, commercial businesses, or power line right of ways, but there are also long sections that are bordered by undeveloped corridors. These undeveloped areas have often lost some of their capacity as floodplains due to past ditching and filling. Before European settlement, this area of the Mud Creek watershed was a set of sinuous creeks connected to a wide floodplain with extensive wetlands. The floodplain/wetland area served a number of functions, including flood water storage and treatment, and was an integral factor in maintaining stream stability and ecological health. Where possible, these undeveloped corridors should be acquired and their floodplain function reestablished by restoring a better hydrological connection to Mud Creek and creating wetlands. Additionally, streams should be restored to a stable configuration that allows more in-stream roughness and pool-riffle sequences. The restoration approach could vary from reconnecting the channel with an adjacent floodplain area (Rosgen priority 1) to constructing appropriate floodplain area and channel form within the existing incised channel (Rosgen priority 2 or priority 3 approach) where adjacent land cannot be acquired.

Based on the recent experience of the North Carolina Wetlands Restoration Program (Haupt et al., 2002) and a number of Maryland counties that have active restoration programs (Weinkam et al., 2001), costs of at least $200 per linear foot (about $1 million per mile) should be expected for the restoration of urban stream channels. If only Mud Creek from Erkwood Rd. to the Clear Creek confluence (4.2 mi), lower Devils Fork (2.6 mi), and the Johnson Drainage Ditch from its confluence with Bat Fork to Mud Creek (1.3 mi) are considered, their restoration would cost approximately 8 million dollars. It is important to consider that any stream restoration work performed is a temporary fix if further urbanization continues in this watershed without the use of adequate post-construction stormwater controls.

In conjunction with the stormwater retrofits discussed earlier, this patchwork approach could lessen the chronic flooding problems of the Hendersonville area. The City of Hendersonville has much interest in this approach and has already acquired two parcels of land adjacent to Mud Creek and intends to reestablish their capacity as flood storage areas.

As mentioned above for upper Mud Creek and Bat Fork, wooded riparian vegetation should be planted or widened where possible in order to provide edge habitat, organic microhabitat, and stream stability.

c) *Non-urban lower Mud Creek (from Clear Creek to the French Broad River).* This system drains more than 100 mi^2 and is a wide stream (up to 100 ft across). Although there are some areas with severe erosion, banks are generally stable and bordered by a line of trees. This system was channelized over 100 years ago and has achieved some degree of stability over time. However, it still has heavy fine sediment deposits and lacks riffles, pools, and bends. Restoration of pattern, profile, and dimension would be expensive on such a large stream and may not be the best use of resources given the relative stability of the channel and the amount of work that should be done elsewhere in the watershed. Instead, an effort to control upstream sediment sources, work with landowners to establish wider woody riparian vegetation along the creek, fence cattle out of the stream, and stabilize the few areas with severe erosion is likely a more cost-effective option.

2) <u>Unstable Tributaries</u>
Unstable tributaries contribute a large amount of sediment to Bat Fork, Devils Fork, and Mud Creek. If these mainstem creeks are stabilized but tributaries are not, there will still be excessive sedimentation in the mainstems. Tributaries should be prioritized for attention according to (1) the contribution of sediment downstream, and (2) the ease of stabilization. Some tributaries could be stabilized by simply fencing cattle out of the creek (e.g., Henderson Creek) and establishing some bank vegetation. Others (e.g., Wash Creek) can only be truly stabilized by restoring pattern, profile, and dimension to handle an urban hydrologic regime. Again, establishing woody riparian vegetation along tributaries can aid in stabilizing some of these creeks over the long-term.

Of note are some unstable areas on Clear Creek. Although sediment is not a cause of impairment for Clear Creek, any sediment in Clear Creek ends up in Mud Creek, which does not have the same capacity to transport sediment. Areas along present and past pasture areas and blow out areas below road bridges are in particular need of stabilization.

Although resources did not allow full investigation of the stability of watershed tributaries, the following were noted as particularly unstable:

Upper Mud Creek subwatershed: Lower Greer Cr.
Clear Creek subwatershed: Lewis Cr. and its tributaries, Henderson Cr., Wolfpen Cr., Allen Br.
Bat Fork subwatershed: Lower King Cr.
Lower Mud Creek subwatershed: Wash Cr., Lower Brittain Cr.

3) <u>Upland Sources of Sediment</u>
A number of upland sources contribute sediment to Mud Creek. According to a sediment loading model developed for TVA's Integrated Pollutant Source Identification (IPSI) (see Section 3.1), eroding roads, residential land, and commercial land are the most significant upland sources for the watershed in general. Field reconnaissance has pinpointed newly disturbed sites as significant sources of sediment, as well.

Many existing commercial and residential sites can serve as notable sources of post-construction sediment. Home and business owners should be encouraged to address sediment sources on their land. Unvegetated and eroding land on slopes should be stabilized and vegetated. Unpaved driveways that are not properly stabilized should be regraded to control erosion.

Unpaved roads should either be retrofitted to control erosion or paved. If unpaved roads are retrofitted, best management practices (BMPs) should be implemented, including proper grading and the construction and maintenance of sediment basins to settle out coarse sediments that erode during storm events. If roads are paved, water velocity should be slowed and runoff allowed to infiltrate in order to control its erosive potential and volume. For both options, eroding road banks should be stabilized with vegetation.

8.1.5 Metals in Rural Areas

High levels of metals in stormflows were noted in the Clear Creek subwatershed and are considered a potential cause or contributor to impairment. In order to determine if these metals have a role in biological impairment, further stormflow monitoring should be performed and sources pinpointed.

8.1.6 Nutrient Enrichment

Although not a cause of impairment for any stream studied, nutrient enrichment is a contributing stressor for the biological communities of Clear Creek and Devils Fork. In upper Clear Creek at Mills Gap Rd., the obvious nutrient source is cattle, which have access to a tributary (Puncheon Camp Creek). Cattle have access to a number of streams in the Clear Creek and Devils Fork subwatersheds. The Henderson County SWCD should work with farmers to fence cattle out of streams.

In addition, straight pipes should be identified and eliminated and failing septic systems fixed. Financial aid for elimination of straight pipes is available through the US Department of Agriculture's 504 Loan and Grant Program. Residents and commercial landscapers should be encouraged to reduce fertilizer use.

8.2 Addressing Future Threats to Stream Integrity

As discussed in Section 2, development is occurring rapidly in the watershed. Continued habitat degradation in the Mud Creek watershed is likely if this development does not employ appropriate sedimentation and erosion control and riparian vegetation is removed. Addressing these future threats is important, or habitat quality improvement resulting from efforts to control current problems may be short-lived. In addition, to avoid significant channel erosion and additional scour, it is critical that effective post-construction stormwater management occur throughout the Mud Creek watershed.

8.2.1 Sediment from New Construction

Significant future sediment inputs from upland sources will continue to degrade in-stream habitat even if existing sources of sediment are addressed. Home building will continue in this quickly growing area, and if current development practices are used, roads, driveways and construction sites will provide a significant source of sediment to streams. Developers of roads and home sites should be encouraged to adhere to best management practices that control erosion in steep areas, quickly stabilizing bare areas with vegetation and limiting development of steeper areas. Private roads with steep grades (>12%) are difficult to maintain and erode easily (Western North Carolina Tomorrow, 1999); construction of these roads should be discouraged.

The State's Sediment and Erosion Control (S&EC) Program, operated by the Division of Land Resources, currently has only one inspector assigned to Henderson County who must review and enforce between 60-80 sediment and erosion control plans each year. Most of the larger developers and contractors operating in Henderson County are familiar with the state's S&EC requirements and compliance is generally acceptable. However, many of the smaller development sites in the county, which fall below the state's one acre threshold for an erosion control plan, do not properly install best management practices to minimize sediment pollution or are unaware of the requirements altogether. This program also was developed to address sediment issues on a state-wide basis and is not specifically designed to address mountain region of North Carolina, which has steeper slopes and higher rainfall levels.

In order to prevent future stream quality deterioration related to new construction activities, sediment and erosion control practices should be improved. Either the NC Division of Land Resources or Henderson County should develop guidelines that better protect waters from the impacts of home and road development on steep slopes. Improved mechanisms for addressing the impacts of disturbances of less than one acre should also be developed. Staffing levels sufficient to support effective enforcement are essential.

8.2.2 Stormwater Issues

Under temporary rules for the Phase II Stormwater Program, Hendersonville, Flat Rock, and Laurel Park are required to develop and implement a comprehensive stormwater management program. This program must include six minimum measures: 1) public education and outreach on stormwater impacts; 2) public involvement/participation; 3) unauthorized discharge detection and elimination; 4) construction site stormwater runoff control; 5) post-construction stormwater management for new development and redevelopment; and 6) pollution prevention/good housekeeping for municipal operations. Henderson County will be required to address measures (4) and (6) unless they are exempted from the rules.

Measure (5) requires control and treatment of post-construction stormwater for the one year 24 hour storm for development that is greater than 24 percent built upon area for Hendersonville, Flat Rock, and Laurel Park. Low density (< 24% built upon area) development is not subject to stormwater control requirements. The 24 percent threshold is not likely to protect downstream channels from significant hydrologic change. A variety of studies (e.g., Schueler, 1994; Bledsoe and Watson, 2001) indicate that impacts to channel morphology and stream habitat degradation occur at levels of imperviousness as low as 10%. Given that channel instability and habitat degradation in Mud Creek and its urban tributaries are already problematic, it is important that additional hydrologic change in the watershed be minimized. Otherwise, existing impairment will be prolonged and exacerbated.

In addition, much commercial and residential development is occurring outside of municipal boundaries, especially along the I-26, US 176, US 25, and US 64 corridors. Without a county-wide program requiring post-construction stormwater management, streams in the watershed will not be protected from new stormwater impacts.

The sensitive channels in this watershed are most likely to be protected from the hydrologic impacts of new development if post-construction stormwater management efforts include:

1. Rapid implementation of the Phase II post-construction stormwater measures in order to minimize future development occurring under current requirements (24% built upon area threshold, control of runoff from the one year 24 hour storm).
2. A county-wide threshold for the use of stormwater controls that is no higher than 10% built upon area. To prevent existing unstable conditions in Mud Creek and its tributaries from deteriorating further, post-construction stormwater control requirements should be applied to all but the lowest density development.
3. Active promotion of infiltration practices and other approaches to limit stormwater volume in both low density and high density development (examples include grassed swales and bioretention areas; see Prince Georges County DER, 2000).
4. Identification of wetland restoration projects or other watershed-based efforts to mitigate for post-construction stormwater impacts (from both new and existing development) that will not otherwise be controlled.

8.3 A Framework for Improving and Protecting Stream Integrity

Watershed restoration of the type necessary to significantly improve Mud Creek and its tributaries is clearly ambitious, but has become more common over the past decade. Local governments and watershed-based organizations have increasingly sought to plan and implement long-term restoration and management strategies that integrate channel, riparian and watershed measures to address stream issues in an integrated fashion. The most long-standing example is probably the restoration of the Anacostia River in the Washington, DC area, for which planning was initiated in the 1980s (Anacostia Restoration Team, 1991; Metropolitan Washington COG, 1998; Galli, 1999; Schueler and Holland, 2000). Among the other areas that have begun to address these issues are Austin, Texas (City of Austin, 2001); Atlanta, Georgia (CH2M HILL, 1998); and Montgomery County, Maryland (Montgomery County DEP, 2001).

The watershed restoration strategy provided here is aimed at restoring biological integrity of streams in the Mud Creek watershed. Public benefits of restoration work are numerous and diverse, including an improvement in the trout and smallmouth bass fisheries, decrease in flooding, safer water for wading and canoeing, and decrease in land lost due to unstable streams.

Restoration projects of this scale require an iterative process of ‘adaptive management’ (Reckhow, 1997; USEPA, 2001). Considering the scope of activities, logistical complexities, and scientific uncertainties, it is not be possible to anticipate all necessary actions in advance. An initial round of management actions must be planned and implemented, the results of those activities monitored over time, and the resulting information used as the basis for planning subsequent efforts. Additional measures should be implemented as appropriate. Improvement in stream condition is likely to be incremental.

An organizational framework for ongoing watershed management is essential in order to provide oversight over project implementation, to evaluate how current restoration and protection strategies are working, and to plan for the future. While state agencies can play an important role in this undertaking, planning is often more effectively initiated and managed at the local level. A coordinated planning effort involving the governments of Henderson County, Hendersonville, Laurel Park, Flat Rock, and East Flat Rock as well as a broad range of other stakeholders, will be critical if conditions in the Mud Creek watershed are to be improved. This effort must include the development of a long-term vision for protecting and restoring the watershed, as well as the specific work that will be necessary to support a patient approach to planning and implementing projects to move toward that vision. The Mud Creek Watershed Restoration Council, composed of representatives from area municipalities, technical staff, business people, and local citizens, has begun this planning effort and has developed a management strategy to address issues named in this report.

8.4 Summary of Watershed Strategies

The following actions are necessary to address current sources of impairment in the Mud Creek watershed and to prevent future degradation. Actions four and five are proposed based on current understanding of apple and row crop pesticide delivery and impacts; strategies should be further refined based on cooperative research by DWQ, NC Department of Agriculture and Consumer Services, NC Division of Soil and Water Conservation, NC State University, NC Cooperative Extension Service, Natural Resources Conservation Service and other agencies. Actions one through five are essential to restoring and sustaining aquatic communities in the watershed.

1. **Feasible and cost-effective stormwater retrofit projects should be implemented throughout the developed portions of the watershed to mitigate the hydrologic effects of development** (increased stormwater volumes and increased frequency and duration of erosive and scouring flows). This should be viewed as a long-term process. Although there are many uncertainties, costs of at least $1 million per square mile can probably be anticipated.
   a) Over the short-term, currently feasible retrofit projects should be identified and implemented.
   b) In the longer term, additional retrofit opportunities should be sought out in conjunction with infrastructure improvements and redevelopment of existing developed areas.
2. **A strategy to address toxic inputs from developed areas should be developed and implemented, including a variety of source reduction and stormwater treatment methods**. As an initial framework for planning toxicity reduction efforts, the following general approach is proposed:
   a) Implementation of available BMP opportunities for control of stormwater volume and velocities. Recommended above to lessen impacts of scour, these BMPs will also remove toxicants from the stormwater system.
   b) Development of a stormwater and dry weather sampling strategy in order to facilitate the targeting of pollutant removal and source reduction practices.
   c) Implementation of stormwater treatment BMPs, aimed primarily at pollutant removal, at appropriate locations.

d) Development and implementation of a broad set of source reduction activities focused on: reducing nonstorm inputs of toxicants; reducing pollutants available for washoff during storms; and managing water to reduce storm runoff. Suggestions for potential source reduction practices are provided.

3. **Stream channel restoration activities should be implemented in order to improve aquatic habitat.**
   a) In order to solve chronic channel instability and habitat problems, restoration of profile, pattern, and dimension should be performed on the channels of upper Mud Creek and Bat Fork. If this option is not pursued, at least woody riparian vegetation should be planted and the streams allowed to heal themselves over time.
   b) In urban areas of Mud Creek, lower Devils Fork, and Johnson Drainage Ditch, undeveloped adjacent lands should be acquired and their floodplain function enhanced, restoring hydrological connection of the floodplains with streams and creating riparian wetlands. In conjunction with the floodplain work, stream restoration should be performed where infrastructure allows.
   c) Woody riparian vegetation should be planted along lower Mud Creek.
   d) Tributaries contributing large amounts of sediment due to in-stream instability should be stabilized.
   e) Livestock should be excluded from mainstem and tributary streams.
4. **Effective BMPs to prevent row crop pesticides from entering streams should be used to address four potential delivery mechanisms**:
   a) Pesticide mixing areas near streams should be replaced with agrichemical mixing facilities that are away from streams and properly manage pesticides.
   b) Riparian vegetation should be planted and stormwater flow diffused through this buffer to reduce pesticides in stormwater runoff.
   c) Backflow prevention systems should be installed in fertigation/chemigation systems.
   d) Pesticide injection into chemigation systems that contain media filters should be on the outlet side of all media filters.
   e) Filter backwash should be recycled or directed away from surface waters.
   f) Eroding banks should be stabilized to minimize erosion of pesticide-contaminated sediments into streams.
5. **Effective BMPs to prevent pesticide contamination of streams from apple orchards should be developed and used**, including:
   a) Pesticide mixing areas near streams should be replaced with agrichemical mixing facilities that properly manage pesticides and are away from streams.
   b) Riparian vegetation should be planted and stormwater flow diffused through this buffer to reduce pesticides in stormwater runoff.
   c) Funding for IPM should be made available to all farmers in the watershed.
   d) Abandoned apple orchards should be dismantled with proper sediment and erosion control to insure that sediments that may contain pesticides stay on site.
   e) Practices to minimize spray drift should be developed and promoted.
   f) Eroding stream banks should be stabilized to minimize erosion of pesticide-contaminated sediments into streams.
   g) Better funding sources should be developed to enable farmers to transition to organic apple growing.
6. Further monitoring should be performed to determine delivery mechanisms of current and past use pesticides and the role past use pesticides in biological community degradation. In

addition, further monitoring of stormflows should be performed in the Clear Creek subwatershed to determine the role of metals in biological impairment.

7. In order to prevent further stream channel and biological community degradation, effective post construction stormwater management must be used in the study area, especially in the rapidly developing US 25, US 176, US 64, and I-26 corridors.
   a) Rapid implementation of the Phase II post-construction stormwater measures in Hendersonville, Flat Rock, and Laurel Park in order to minimize future development occurring under current requirements.
   b) A county-wide threshold for the use of stormwater controls that is no higher than 10% built upon area. To prevent existing unstable conditions in Mud Creek and its tributaries from deteriorating further, post-construction stormwater control requirements should be applied to all but the lowest density development.
   c) Active promotion of infiltration practices and other approaches to limit stormwater volume in both low density and high density development.
   d) Identification of wetland restoration projects or other watershed-based efforts to mitigate for post-construction stormwater impacts that will not otherwise be controlled.
8. Henderson County should develop a sediment and erosion control program or NC Division of Land Resources should refine its present program, with specific provisions to address smaller sites and road and site development on steep slopes. Staffing levels sufficient to support effective enforcement are essential.
9. A watershed education program should be developed with the goal of reducing current stream damage and preventing future degradation. At a minimum the program should include elements to address the following issues:
   a) Redirecting downspouts to pervious areas rather than routing these flows to driveways or gutters.
   b) Protecting existing wooded riparian areas on perennial, intermittent, and ephemeral streams.
   c) Replanting native riparian vegetation on perennial, intermittent and ephemeral channels where such vegetation is absent.
   d) Reducing and properly managing pesticide and fertilizer use.

Section 9
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